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ALTERNATIVE EMPLOYMENT CONCEPTS FOR REMOTELY PILOTED VEHICLE (R--ETC(U)

DEC 81 W G HOWARD, W K EVANS, S SHRIER DAAK50-80-C-0011

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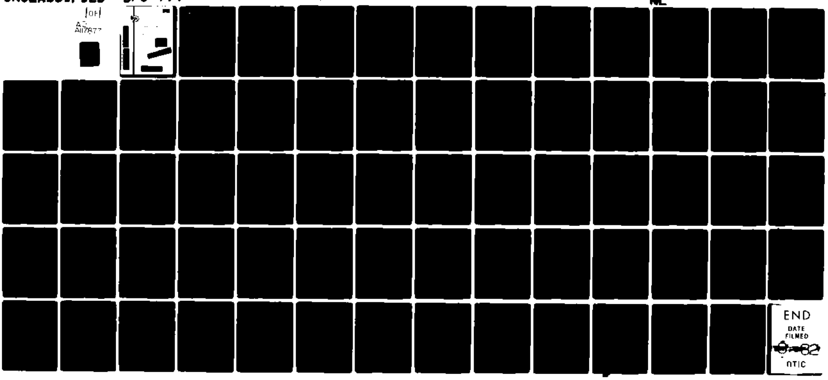

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SYSTEM PLANNING CORPORATION

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FINAL REPORT

SPC 774

December 1981

W. G. Howard
W. K. Evans
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Submitted to

Project Manager's Office
Tactical Airborne Remotely Piloted Vehicle/Drone Systems
U.S. Army Aviation Research and Development Command
St. Louis, Missouri 63120

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I. EXECUTIVE SUMMARY

A. PURPOSE

Under contract to the Project Manager, Tactical Airborne Remotely Piloted Vehicle/Drone Systems, System Planning Corporation was tasked to recommend a mix of TV and FLIR sensors that would provide the most cost-effective day/night RPV system capability. As part of this task an effort was undertaken to identify and assess concepts of employment that would support a broader range of mix options than the current concept. This report provides the results of that effort.

B. DISCUSSION

At the outset of the FLIR/TV mix study, it was expected that a mix of sensors would be required in the basic load of an RPV section. This examination of alternative employment concepts was undertaken because it appeared that operational difficulties of backup and resupply of a mixed basic load might constitute a significant problem area. The study aimed towards greater flexibility for operations with a sensor mix by pooling all the RPV air vehicles in a single launch and recovery section, which would be responsible for providing air vehicles to the operations sections on demand. Additional operational advantages accrue if the launch and recovery section is located to the rear, out of enemy artillery range. Thus, this concept is called rear area launch and recovery.

As the FLIR/TV mix study proceeded, it became apparent that mixed sensor loads within an RPV section might not be required. No significant environmental conditions were found in which the TV would meet the required operational capability (ROC) performance requirements and the FLIR would not, assuming that each sensor achieves its projected performance

characteristics. Although the TV is expected to accomplish detection, recognition, and identification at longer ranges than the FLIR under favorable conditions--good visibility, no cloud cover, and bright background--the FLIR should meet the ROC performance requirements under these same conditions. Moreover, the FLIR is expected to meet the ROC performance requirements under more severe conditions than is the TV--at night, in degraded weather, and in the presence of battlefield-induced contaminants.

The technical and schedule risks associated with the FLIR payload are greater than those associated with the TV payload. A TV mission payload has been demonstrated in the RPV advanced development program and is currently in full-scale development. The FLIR sensors currently in the advanced development program are larger, heavier, and inherently lower in resolution than the TV sensor. At this writing, it has not been demonstrated that a mission payload of the size and weight required for the RPV can, in fact, be produced with a FLIR sensor.

Given the tactical capabilities provided by the TV payload and the technical and schedule risk still associated with the development of a FLIR mission payload, it is prudent to field the daylight system as soon as possible to provide an early capability for those divisions where the need is most critical. As the FLIR becomes available, additional RPV sections can be equipped with FLIR sensors, with no requirement for a mix of sensors within any RPV unit. The rear area launch and recovery concept may nevertheless be worth considering as an employment alternative because of other potential advantages with regard to manpower, equipment, and operational potential. This report compares this concept with independent sections in each of these respects. Since the number of RPV sections in a division may be subject to change, comparisons were made for divisions with three, four, and five RPV sections.

C. FINDINGS

1. Neither manpower requirements nor major equipment requirements provide a basis for a choice between independent sections and rear area launch and recovery. The manpower requirements for both concepts are about the same for a division with four RPV sections. A division with independent sections would require perhaps 10 percent less manpower than one with rear area launch and recovery if there are three RPV sections, and about 10 percent more if there are five sections. Similarly, on the basis of current cost estimates, it appears that major equipment for a division with independent sections would have life-cycle costs slightly less than those for a division with rear area launch and recovery when the division has three sections, about the same with four sections, and slightly more with five sections.

2. A high probability of successful handoff and reliable communications are required to make the rear area launch and recovery concept a viable option. The RPV system in a division with rear area launch and recovery cannot be operationally effective in a hostile electronic environment unless the launch and recovery section and the operations sections can reliably exchange the information required to coordinate RPV missions and effect air vehicle handoff with a high probability of success. The tactical FM radios currently planned for use by the RPV units do not provide reliable communications at the ranges between the rear area launch and recovery section and the operations sections (15 to 20 kilometers) in many geographical areas. The capability to hand off the air vehicle on a routine basis has not yet been demonstrated.

3. Resupply time for a division with independent sections may seriously limit the capability for RPV sorties on a sustained basis. In this study, the measure of operational capability was taken to be the probability that air vehicles will be available on a sustained basis for all required sorties in a specified period. This probability, called sortie potential, depends on basic load, loss rate, and resupply rate. It was assumed that, based on the FLIR/TV mix study, the RPV section would not have

a mix of sensors. If the RPV section does have a mix of sensors as is presently proposed, the sortie potential will be lower than the values shown here. The values for a division with independent sections would be more severely reduced than those for a division with rear area launch and recovery.

In Central Europe, a division with four independent sections, each with a basic load of five air vehicles equipped with TV paylcads and experiencing a per sortie loss rate of 0.30, will have a sortie potential of about 0.80 over the winter 8-hour daylight period if the resupply time is 20 hours. In summer, with 16 hours of daylight, the sortie potential would be less than 0.50. The sortie potential would be restored to 0.80 if the resupply time is 12 hours.

Introduction of the FLIR payload, and therefore 24-hour RPV mission capability, makes resupply time even more critical since there is no longer a quiet (night) period. During any 8-nour period in surge operations, the sortie potential would be less than 0.70 with a resupply time of 12 hours and 0.80 with a resupply time of about 8 hours. Resupply time would have to be 5 hours or less to provide a sortie potential of 0.90 or greater. Increasing the basic load to the next feasible level--eight air vehicles per section--would provide a sortie potential of almost 1.0 for resupply times as long as 24 hours.

If the RPV sections must accomplish their own resupply, resupply times in an intense battle are estimated to be at least 12 and possibly as much as 20 hours. Even if these estimates are high by a factor of two, a division with independent sections may have a limited capability to provide RPV sorties on a sustained basis.

If, on the other hand, the independent sections could be resupplied through regular supply channels, resupply time might be reduced since the requirement would be transmitted electrically to the supply point rather than by the sections' air vehicle cargo trucks. However, the RPV would have to compete with other high priority systems for the available transport. Sortie potential could also be increased by initiating resupply requests after the loss of one or two air vehicles since the resupply vehicle

would not have to carry three air vehicle containers. Resupply could be accomplished by truck or helicopter, depending on the priority assigned the RPV system.

4. A division with rear area launch and recovery will have a high sortie potential with a basic load of only 13 air vehicles. The rear area launch and recovery section presents a simpler resupply problem because it will be located closer to DISCOM and also will displace less often than an independent section. Resupply times of 6 to 10 hours can be anticipated. In addition, pooling of the division's air vehicles reduces the probability that combat losses can exhaust the supply of air vehicles. As a consequence, with a basic load of 13 air vehicles, the sortie potential will exceed 0.90 for all of the mission conditions previously discussed for independent sections.

II. OPERATIONAL POTENTIAL

A. INTRODUCTION

The RPV system supports the field artillery by acquiring targets and combat information in real time, beyond line of sight of the supported units. The RPV unit, in response to the supported field artillery unit, launches an air vehicle with a mission payload capable of providing the required information, controls the air vehicle and the mission payload in the performance of the mission, and recovers the air vehicle when the mission is completed or its fuel is depleted to a designated level. It is important to be able to launch a sortie when it is required and to maximize the time spent in performance of the mission. These capabilities are dependent on the following factors:

- Organizational and operational concept
- Basic load of air vehicles
- Sensor mix
- RPV system vulnerability
- RPV system reliability
- Maintenance
- Resupply
- Mission coordination.

These factors are discussed in the following section and are used in the subsequent derivation of sortie potential, mission times, and cycle times. Detailed descriptions of the calculations used for this analysis are contained in Appendixes A and B.

B. OPERATIONAL FACTORS

1. Organizational and Operational (O&O) Concept

Two basic O&O concepts for the RPV unit in the division are examined

in this report. One is the present concept of four autonomous RPV sections supporting field artillery battalions assigned either a direct support or a general support mission; the other is a centralized launch and recovery concept where a rear area launch and recovery section provides the air vehicles for the RPV operations sections that support the same field artillery units as in the present concept. The independent RPV section is the basis for the current O&O concept for daylight operations with the TV sensor, 24-hour operation when FLIR sensors are introduced into the inventory, and the Division 86 concept.

a. Current O&O Concept

The current O&O concept for daylight operations with the TV sensor is provided in Target Acquisition/Designation and Reconnaissance System (TADARS), YMQM-105, Organizational and Operational Concept (Updated), 20 October 1980 [Ref. 1]. Under this concept the RPV system is an organic element of the AIM division target acquisition battery and is organized as an RPV platoon. The platoon consists of a platoon headquarters and four independently organized RPV sections as shown in Figure 1. Consideration is currently being given to organizing some RPV platoons with three sections.

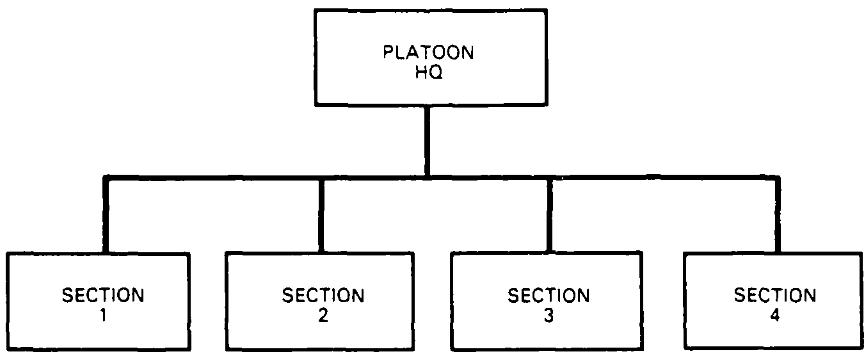

FIGURE 1
RPV PLATOON ORGANIZATION UNDER THE CURRENT O&O CONCEPT

Each section is sufficiently manned and equipped to provide air mission support of a field artillery battalion during daylight hours. An RPV section will be located near and support each of the three brigade direct support field artillery battalions and the division general support field artillery battalion.

b. O&O Concept for 24-Hour Operations

It is anticipated that the basic organizational concept, as currently described for daylight operations, will not change with the introduction of the FLIR sensor except that the manning and equipage of each section wi be increased to support around-the-clock operations.

c. Division 86 Concept

There is no RPV platoon in the Division 86 Concept [Ref. 2]. An RPV section, manned and equipped for 24-hour operations, is organic to each of the three direct support and two general support target acquisition platoons. Each division will have five RPV sections as shown in Figure 2.

d. Rear Area Launch and Recovery Concept

In the rear area launch and recovery concept postulated herein, all RPV air vehicles in the division are in a launch and recovery (L/R) section located well to the rear of the immediate zone of contact. The direct support and general support field artillery units are supported by RPV operations sections. The RPV platoon organization is shown in Figure 3. The L/R section has two complete L/R teams, which is necessary to provide adequate service to three, four, or five operations sections and to permit operations to continue during L/R section displacement. The relationship between the operations sections and the field artillery units is the same as in the independent section concepts. An operations section is located near the field artillery unit it supports and is responsive to the requirements of the unit. The operations section, in response to the field artillery unit, asks the L/R section to provide an air vehicle. An L/R team launches the air vehicle, guides it to a prearranged area, and hands it off to the

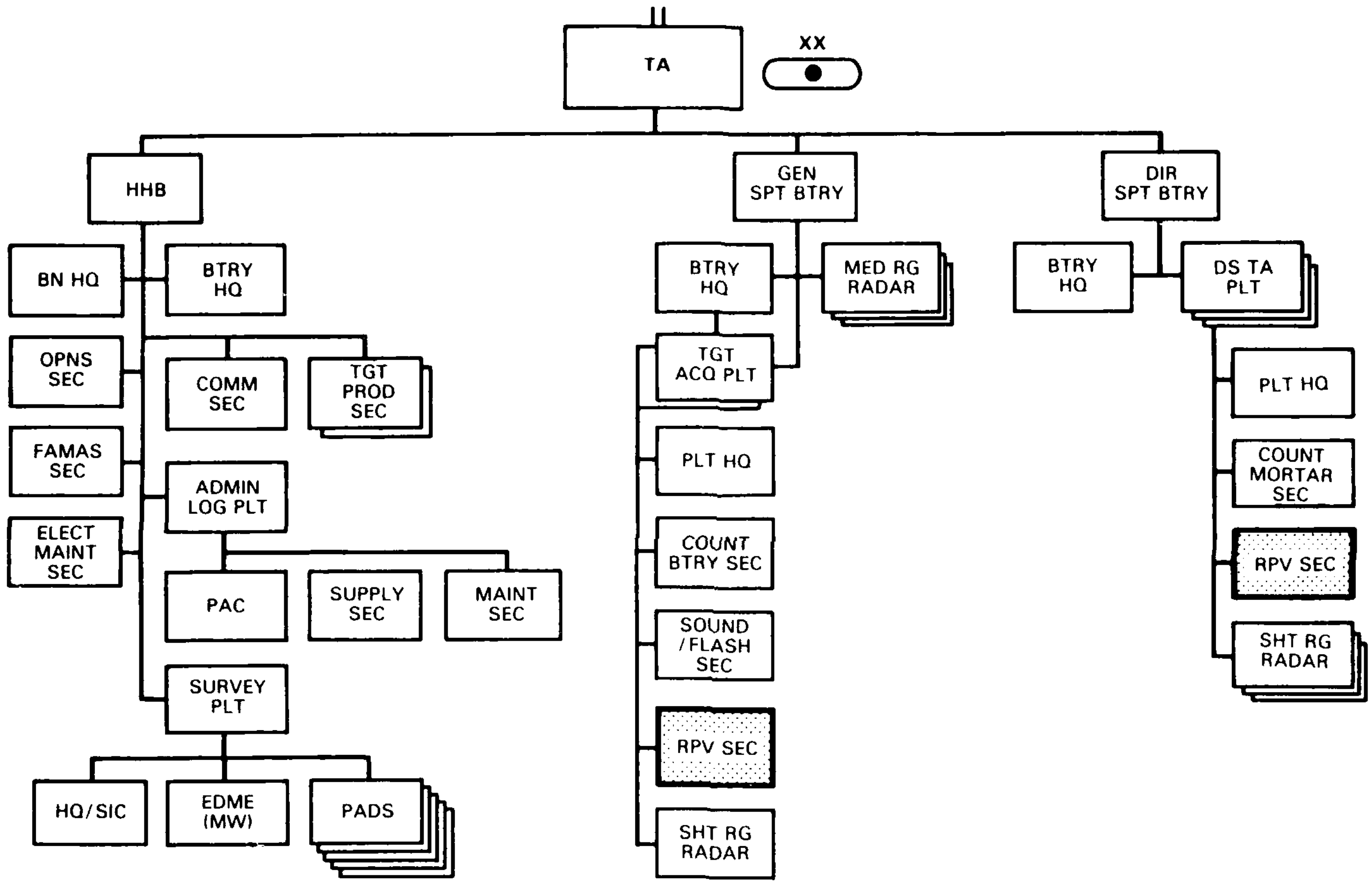

FIGURE 2
DIVISION TARGET ACQUISITION BATTALION ORGANIZATION IN THE DIVISION 86 CONCEPT

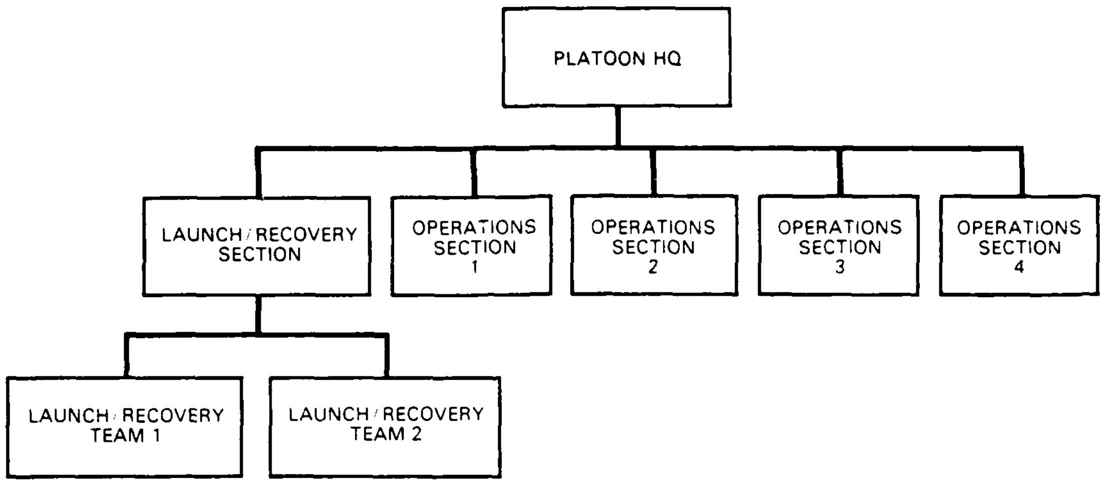

FIGURE 3
RPV PLATOON ORGANIZATION UNDER THE REAR AREA LAUNCH AND RECOVERY CONCEPT

operations section. The operations section conducts the RPV mission in support of the field artillery unit, returns the air vehicle to a prearranged area, and hands it off to an L/R team for recovery.

2. Basic Load

Basic load is a factor in determining the length of time an RPV unit can operate under a given set of battle conditions before resupply must be accomplished. Basic load determines how long a given consumption rate can be sustained; it has no effect on the consumption rate.

In the current O&O concept each RPV section has a basic load of five air vehicles. Two air vehicles are carried on the air vehicle handler and three on an air vehicle cargo truck. There are no present plans to increase the basic load when the section has a 24-hour operational capability. However, if the basic load is increased it would logically be accomplished by adding another air vehicle cargo truck with three air vehicles.

In the rear area launch and recovery concept, the basic load of the L/R section has not been determined. It would be carried on two air vehicle handlers and a number of air vehicle cargo trucks. The basic load could be 7, 10, 13, 16, or 19 air vehicles. This is examined later in this study.

3. Sensor Mix

In the FLIR/TV Mix [Ref. 3] report, published under separate cover, it was shown that if the FLIR mission payload meets its projected performance characteristics, there would not be a continuing requirement for a TV payload. Since the TV payload will be available at least 2 years before the FLIR, it is assumed that some divisions would be equipped with TV payloads to provide an interim daylight capability and that the TV payloads would be phased out of the system when the FLIR payloads become available. Under these circumstances an RPV unit would never have a mix of sensors in its basic load.

4. RPV System Vulnerability

The RPV system is vulnerable to enemy action that may reduce the RPV unit's capability to generate sorties when they are required and to maintain an air vehicle in the mission area. The ground systems are vulnerable to enemy artillery and aircraft. The air vehicle will be exposed to enemy air defenses while performing its mission, and its vulnerability will be the principal cause of air vehicle losses in combat.

RPV system vulnerability is the subject of separate ongoing studies, and specific values are not yet available. A range of values for air vehicle vulnerability is therefore examined to determine the effect on operational potential. The vulnerability of the ground systems is addressed qualitatively.

5. RPV System Reliability

RPV system reliability is a contributing factor to sortie potential both from air vehicle and ground control system (GCS) failures causing loss

of an air vehicle during a mission and failures causing down time for maintenance.

Minimum acceptable values (MAV) for RPV system reliability are stated in the Required Operational Capability (ROC) [Ref. 4]. The RPV full-scale development (FSD) contractor has stated that the achieved reliabilities should be in excess of the MAV in every case. However, since no data have yet been collected to establish actual reliability values, and since MAV have not yet been established for the FLIR payload, the MAV stated in the ROC and included in the FSD contract are used in this study for both the TV and FLIR systems.

6. Maintenance

The RPV system will be maintained in the four-level general maintenance system--organizational, direct support (DS), general support (GS), and depot.

The FSD contract requires that the RPV system be designed so that 90 percent of all failures can be corrected at organizational level with a mean time to repair of 30 minutes. The remaining 10 percent must be repairable by the direct support level with a mean time to repair of 2.0 hours.

The details of how direct support maintenance will be provided have not yet been decided. One proposal is that direct support contact teams will respond to calls from the RPV sections. In a battle situation the brigade direct support maintenance could be expected to provide a contact team to the RPV section supporting the brigade in a reasonably short period of time. In this study it is assumed that for the O&O concept with independent sections the direct support team will respond in 1.0 hour. In the rear area launch and recovery concept, it is assumed that direct support contact teams will respond to the L/R section in 30 minutes. Response by the direct support teams to the operations section will be the same as for the independent sections.

7. Air Vehicle Resupply

Neither the criteria for initiating air vehicle resupply nor the pro-

cess for accomplishing it has yet been determined. However, there is a strong possibility that the RPV section will have to accomplish its own resupply. The currently planned structure of the section limits its resupply options. It will have one air vehicle handler that carries two air vehicles and assists in launch and recovery operations and one air vehicle cargo truck that carries three air vehicles. The section will have no other capability for storing or carrying air vehicles. With such a structure the section will probably not initiate resupply until the air vehicle cargo truck has three empty air vehicle containers. The section will then have only two air vehicles remaining.

Resupply will likely be accomplished in the following manner: When the air vehicle cargo truck is empty it will be dispatched, with a driver and an assistant, to the air vehicle supply point to exchange the three empty air vehicle containers for full ones. Assuming that the air vehicle supply point is at DISCOM, the driver of the air vehicle cargo truck will probably not know its exact location when he leaves the section site, although he will know that it is in the rear of the division area. He will make his way toward the rear on crowded roads and could spend considerable periods of time pulled off the road waiting for priority traffic to pass. On reaching the rear area he will find DISCOM by making inquiries along the way, since air vehicle cargo trucks do not have radios. Within DISCOM he must still find the specific location of the air vehicles. (The air vehicle supply point must have a crane or forklift to unload the empty air vehicle containers and load the full ones.) After getting his load of air vehicles, the driver will make his way back to the front, again with possible delays from traffic and route uncertainties. When he reaches the brigade front area, his RPV section may have displaced once, and probably twice, since he left. He will therefore have further delays in finding the section site.

The distance between the RPV section and DISCOM will probably be between 35 and 50 kilometers. It is unlikely that the driver could average more than 8 to 10 kilometers per hour on the road between the section site and DISCOM. He could be expected to spend 2 to 4 hours finding the air vehicle supply point at DISCOM and getting his load of air vehicles. He could

spend another 1 to 2 hours locating his section after getting back to the brigade front area. The time from leaving the section after the third air vehicle is lost to getting back to the section with three new air vehicles is estimated to be at least 12 hours and could easily be as much as 20 hours.

The rear area L/R section will have a simpler resupply problem, since it will be located closer to DISCOM and will displace less often than an independent section. The resupply truck driver would not have the traffic congestion near the front to contend with and would have an easier time locating the L/R section on return. Using the same type of reasoning as used above for an independent section, it is estimated that the rear area L/R section will have a resupply time of 6 to 10 hours.

These estimates of resupply time are believed to be realistic for the confused situation that exists in an intense battle. However, the analysis that follows provides an estimate of sortie potential as a function of resupply time so that a broad range of values for resupply time can be examined.

8. Mission Coordination

The RPV ground control station must accomplish two types of mission coordination: with the supported field artillery unit and with the RPV launch and recovery unit. Coordination with the supported field artillery unit is accomplished in the same manner by the independent sections and the operations sections with rear area launch and recovery, and is not considered further in this study.

In independent sections the ground control station and the launch and recovery section are separated by a few hundred meters at most. Information passes between them by wire or by short-range FM radio. If necessary a messenger can carry information from one to the other quickly. The ground control station participates in the prelaunch activities and is in control of the air vehicle when it is launched.

In the rear area launch and recovery concept the operations section and the L/R section must accomplish mission coordination while separated by

15 to 20 kilometers. To plan a mission the L/R section must be informed of the need for the mission and know the location of the remote ground terminal of the operations section that will acquire the air vehicle and conduct the mission. The operations section must know the time when the air vehicle will be handed off to it, the location in space where the handoff will take place, and the technical data required to take control of the air vehicle. When the air vehicle is returned for recovery, the operations section must know the location of the remote ground terminal of the L/R section and the L/R section must know when the air vehicle is being returned and the location in space where the handoff is planned. The L/R section, having launched the air vehicle, would have the technical data required to take control of the air vehicle.

In the computations of operational potential it is assumed that mission coordination is accomplished without delay. The implications of this assumption are addressed qualitatively.

C. RPV OPERATIONS

The two components of operational potential previously mentioned--mission coverage (the proportion of time that an air vehicle can be kept in the mission area) and sortie potential (the capability to generate the sorties required)--can be estimated for divisions with independent sections and divisions with rear area launch and recovery. The remainder of this chapter examines these two components for divisions with three, four, and five RPV sections. Sortie potential is examined for RPV units equipped with TV mission payloads and with around-the-clock capability. Calculations of expected sortie times and resulting values of mission coverage are contained in Appendix A.

1. Mission Coverage

Mission coverage can be estimated using the same basic procedures that were used in the System Planning Corporation report, Control of Multiple Remotely Piloted Vehicles, December 1979 [Ref. 5]. Each possible outcome of a sortie attempt is identified, and the probability and times associated

with these events are derived based on expected or assumed operational parameters as well as the system reliability and air vehicle vulnerability assumptions. Two times can be associated with each possible outcome: the time of mission coverage (T_m) and replacement time (T_r) (i.e., the time from the end of mission coverage on one sortie until coverage begins on the next). The sum of these two times is cycle time (T_c), the time from the start of one period of mission coverage to the start of the next. Using the associated probabilities, the expected per-sortie times can be calculated. The ratio of T_m to T_c is an estimate of mission coverage.

Expected sortie times of independent sections were calculated for different values of air vehicle survivability to determine the effect on mission coverage. Table 1 shows the sortie times and mission coverage for probabilities (P_s) of surviving a 160-minute mission equal to 0.75, 0.90, and 1.00.

TABLE 1
SORTIE TIMES AND MISSION COVERAGE--
INDEPENDENT SECTIONS

P_s	Mission Time T_m (min)	Replacement Time T_r (min)	Cycle Time T_c (min)	Mission Coverage T_m/T_c
0.75	125	24	149	0.84
0.90	136	26	162	0.84
1.00	142	27	169	0.84

As survivability of the air vehicle increases, mission time is increased but so is replacement time, so that mission coverage remains the same.

In a division with independent sections, each section has the capability to launch a sortie when it is required as long as it has an air vehicle available. For a given survivability rate, T_m and T_r would be expected to be unchanged in the different battle situations.

In a division with rear area launch and recovery, T_m would not be expected to change for a given survivability rate and probability of successful handoff. T_r, however, varies with the number of launch and recovery

teams and the demand for sorties, both of which may vary with the battle situation. In a surge situation it is expected that the operations sections will each displace three times a day while the launch and recovery section will displace once a day, one launch and recovery team at a time. T_r would be expected to increase while the launch and recovery section was displacing, due to the reduction in the capability to respond to the demand for sorties. Likewise, if the battle situation is such that all the operations sections are making an all-out effort and no displacements take place, the demand for sorties will be greater and T_r would increase.

The expected sortie times and resulting values of mission coverage are calculated in Appendix A and summarized in Table 2 for divisions with three, four, and five sections when the probability that an air vehicle will survive a 160-minute mission is 0.75 and the probability of a successful handoff is 0.99.

Divisions with rear area launch and recovery would expect mission coverage as good or better than those with independent sections except when the launch and recovery section was displacing. At that time a division with four sections would expect queue delays averaging about 45 minutes on about two-thirds of the sorties, and a division with five sections would expect delays of about 1 hour on about three-fourths of the sorties.

TABLE 2
EXPECTED SORTIE TIMES AND MISSION COVERAGE

Situation	Mission Time T_m (min)	Replacement Time T_r (min)	Cycle Time T_c (min)	Mission Coverage T_m/T_c
Independent sections, all situations	125	24	149	0.84
Rear area launch & recovery, three sections				
Surge with 2 L/R teams	115	14	129	0.89
Surge with 1 L/R team	115	24	139	0.83
All-out effort	115	15	130	0.88
Four sections				
Surge with 2 L/R teams	115	16	131	0.88
Surge with 1 L/R team	115	41	156	0.74
All-out effort	115	18	133	0.86
Five sections				
Surge with 2 L/R teams	115	18	133	0.86
Surge with 1 L/R team	115	55	170	0.68
All-out effort	115	22	137	0.84

2. Sortie Potential

Sortie potential can be quantified as the probability that a division will have the air vehicles available to conduct the sorties required in a given period of time. Sortie potential is a function of basic load, loss rate, and resupply rate. The number of sorties required is determined by the period of time selected, the number of RPV sections in the division, the battle situation, and the sortie cycle time. The calculation of sortie potential is discussed, and estimates of sortie potential in a variety of operational conditions and battle situations are provided in Appendix B. This section provides a comparison of sortie potential of divisions with independent sections and divisions with rear area launch and recovery for some representative conditions. It is assumed, on the basis of previous work [Ref. 3], that the RPV section will have either FLIR or TV sensors, not a mix. If the RPV section does have a mix of sensors, as is presently proposed, the values of sortie potential will be lower than those shown in this report since the probability of having the required sensor at the required time will be less than 1.0. The values for a division with independent sections would be more severely reduced than those for a division with rear area launch and recovery because of the relatively small basic load at each independent section.

a. Daylight Operations

The RPV is expected to be fielded initially with a TV mission payload and operate in that configuration for at least 2 years before the FLIR mission payload is available. Operation with the TV payload will be limited to daylight hours. In a surge situation each RPV section will conduct one sortie after another, interrupted only by the requirement to displace. Table 3 shows the expected number of sorties per day in 8, 12, and 16 hours of daylight for divisions with four RPV sections when the probability that an air vehicle will survive a 160-minute mission is 0.75 and the probability of a successful handoff is 0.99. The daylight sortie potential of a division with four independent sections when there are 8 hours of daylight, for example, is the probability of having air vehicles available for 13 sorties per day.

TABLE 3
EXPECTED NUMBER OF SORTIES IN DAYLIGHT HOURS

	Hours of Daylight 8	12	16
Displacements in daylight	0	1	2
Operational hours	8	10	12
Expected number of sorties			
Four independent sections	13	16	19
Four operations sections	14	18	22

Figure 4 shows the relationship between sortie potential and resupply time under the above conditions for a division with four independent sections, each with a basic load of five air vehicles. While RPV operations are limited to daylight hours, resupply can go on around the clock. Thus, when there are 8 hours of daylight, a section can start off each day's operation with its full basic load if it can accomplish resupply in 16 hours or less. It was previously estimated that an independent section could accomplish its own resupply in 12 to 20 hours.

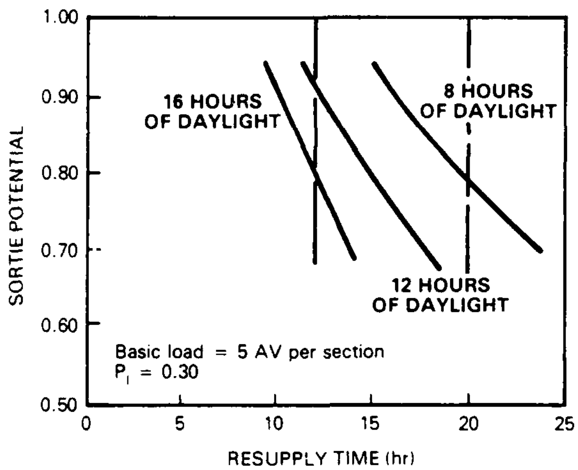

FIGURE 4
DAYLIGHT SORTIE POTENTIAL OF DIVISIONS WITH 4 INDEPENDENT SECTIONS

If resupply can be accomplished within 12 hours, sortie potential will be greater than 0.90 when there are 12 hours or less of daylight, approximately one-half of the year. On the other hand, if resupply takes 20 hours, sortie potential will always be less than 0.80. An independent section must be able to accomplish resupply in 10 hours or less to ensure a sortie potential of at least 0.90 throughout the year.

A division with three independent sections will have sortie potential slightly higher and one with five independent sections slightly lower than that shown in Figure 4 for four sections. The statements made above would still apply to both cases.

Figure 5 shows the relationship between sortie potential and resupply time under the stated conditions for divisions with rear area launch and recovery and three, four, and five operations sections, with a basic load of 10 air vehicles, when there are 16 hours of daylight. It was previously estimated that a rear area launch and recovery section could accomplish resupply in 6 to 10 hours. If resupply can be accomplished in 6 hours, sortie potential will be greater than 0.90 all year for divisions with three, four, or five operations sections and a basic load of 10 air vehicles. If resupply takes 10 hours a division with five operations sections would have a sortie potential slightly under 0.90 in the summer months.

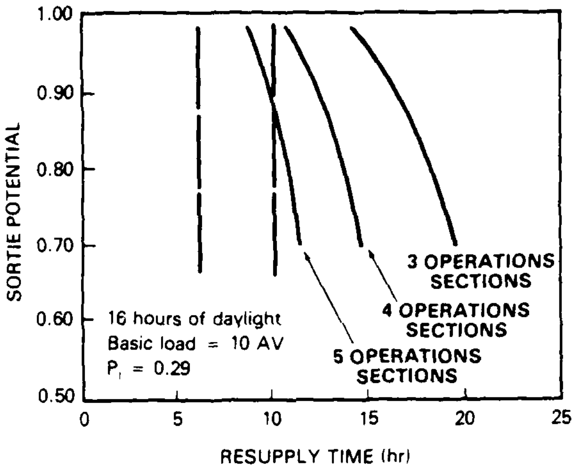

FIGURE 5
DAYLIGHT SORTIE POTENTIAL OF DIVISIONS WITH REAR AREA LAUNCH AND RECOVERY

If the RPV is employed in Europe with the TV mission payload, a division with rear area launch and recovery and a basic load of 10 air vehicles would expect a higher sortie potential than a division with independent sections and a total basic load of 20 air vehicles.

b. Around-the-Clock Operations

In around-the-clock operations, it is expected that there will be occasions when the RPV units must make an all-out effort, with a requirement to generate one sortie after another for extended periods. This section examines the sortie potential of divisions with independent sections and divisions with rear area launch and recovery for an 8-hour period of all-out effort when the probability that an air vehicle will survive a 160-minute mission is 0.75 and the probability of a successful handoff is 0.99.

Figure 6 shows the relationship between sortie potential and resupply time, under the stated conditions, for a division with four independent sections, each with basic loads of five and eight air vehicles. The relationship is essentially the same for divisions with three or five independent sections. A division with three, four, or five independent sections each with a basic load of five air vehicles will not have a high sortie potential with the estimated capability to accomplish resupply of between 12 and 20 hours. It must have a resupply time close to 5 hours to have a sortie potential of 0.90. If the basic load of each section is increased to eight air vehicles, the smallest increment possible, a division with three, four, or five independent sections will have a sortie potential close to 1.00 with the estimated capability to accomplish resupply.

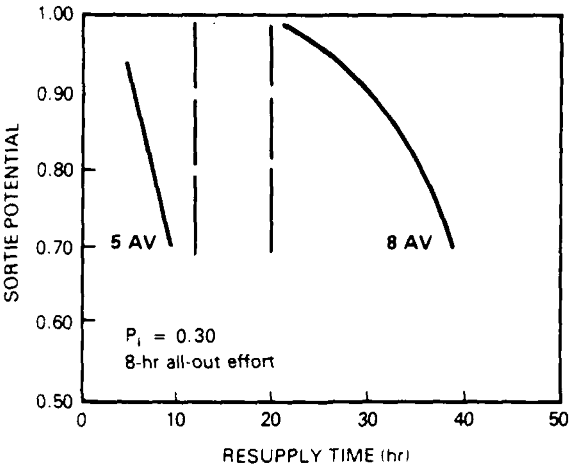

FIGURE 6
SORTIE POTENTIAL OF DIVISIONS WITH 4 INDEPENDENT SECTIONS

Figure 7 shows the relationship between sortie potential and resupply time, under the stated conditions, for a division with rear area launch and recovery and four operations sections. The relationship is shown for the cases when the rear area launch and recovery section has a basic load of 10, 13, and 16 air vehicles. A basic load of 13 air vehicles will provide a high sortie potential with the estimated resupply capability of 6 to 10 hours.

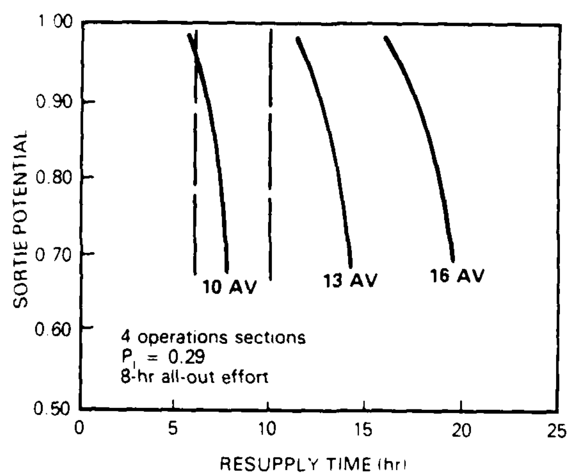

FIGURE 7
SORTIE POTENTIAL OF DIVISIONS WITH REAR AREA LAUNCH AND RECOVERY

Figure 8 shows the relationship between sortie potential and resupply for divisions with rear area launch and recovery and three, four, and five operations sections when the rear area launch and recovery section has a basic load of 13 air vehicles. It shows that a basic load of 13 air vehicles will provide a sortie potential greater than 0.90 for all the cases with the estimated resupply capability.

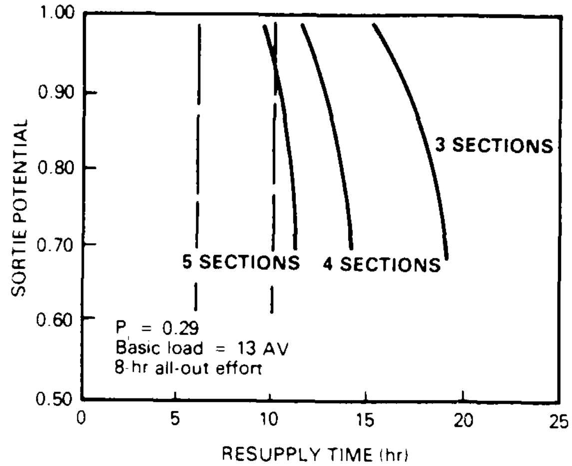

FIGURE 8
SORTIE POTENTIAL OF DIVISIONS WITH REAR AREA LAUNCH AND RECOVERY

Figure 9 shows the sortie potential of divisions with four independent sections, with basic loads of five and eight air vehicles per section and divisions with four operations sections and a rear area launch and recovery section with basic loads of 10, 13, and 16 air vehicles. Rear area launch and recovery provides a high sortie potential with a small basic load. It also provides greater flexibility to adjust the basic load to the resupply time that can be achieved. The relationship between sortie potential and resupply time is essentially the same for a division with four independent sections, each with a basic load of five air vehicles, and a division with four operations sections and a rear area launch and recovery section with a basic load of 10 air vehicles. In both cases, the resupply time is probably less than can be achieved in a surge situation. It is necessary to increase the basic load to

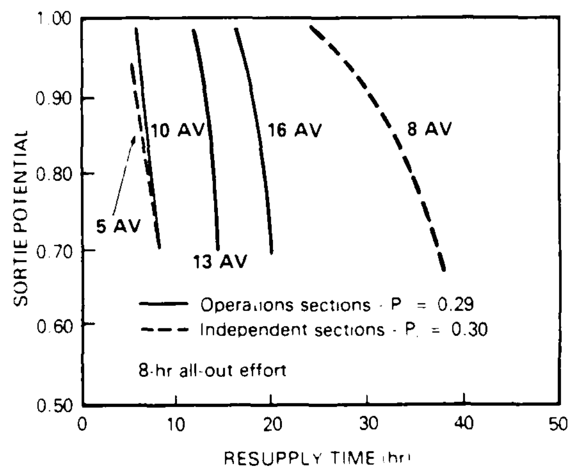

FIGURE 9
SORTIE POTENTIAL OF DIVISIONS WITH 4 RPV SECTIONS

provide a high sortie potential with a larger resupply time. In the division with independent sections, the basic load of each section will be increased to 8 air vehicles--a total of 32 air vehicles for the division. This provides a high sortie potential with a resupply time much greater than is probably required. In the division with rear area launch and recovery, the basic load can be increased in units of three air vehicles, and a selection can be made so that the basic load is the minimum consistent with the requirement for resupply time and the desired sortie potential.

3. Other Considerations

a. Air Vehicle Resupply

Based on the assumption that the RPV section would accomplish its own air vehicle resupply, the preceding analysis showed that resupply time is more critical to the operational potential of the independent section than to the rear area launch and recovery section. This is primarily the result of allocating only one air vehicle cargo truck to an independent section and the resulting requirement to initiate resupply after three air vehicles have been lost out of the basic load of five. Resupply time might be reduced for the independent sections if they could be reliably resupplied through regular supply channels, by truck or helicopter, depending on the priority assigned the RPV mission. Resupply would be accomplished on demand since air vehicle losses are expected to occur at random and a replacement air vehicle cannot be accomodated until the section has an empty air vehicle container. The cost of resupply, in personnel and transport equipment, would be added to the logistics system, and the RPV system would have to compete with other high priority systems for the available transport. Resupply of air vehicles would require a round trip between the supply point and the RPV section to deliver the air vehicles and return the empty air vehicle containers.

In an emergency, an independent section might be able to get an air vehicle from an adjacent section by handoff in flight. The implementation of this capability would require communication and coordination between adjacent sections that are not currently planned.

b. Mission Coordination

As indicated earlier, mission coordination presents no problem in an independent section since all involved activities are at the same location, and the GCS has control of the air vehicle when it is launched. With the launch and recovery element in the rear area and separated from the operations sections by 15 to 20 kilometers, the exchange of information necessary for mission coordination may be a problem. The tactical FM radio planned for use in the RPV system does not provide reliable communications at ranges of 15 to 20 kilometers in many geographical regions because of terrain masking. Some of the required coordination can be accomplished in advance. For example, the handoff from and the return to the L/R section can be planned for locations in fixed relationships to the operations section. Similarly, the operations section could be provided the technical data required to take control of an air vehicle for several missions in the order that they would be used. There are some aspects of mission coordination, however, that cannot be planned in advance or handled procedurally, such as the requirement for another air vehicle to replace one that is lost in the mission area. These aspects of mission planning are time critical and must be accomplished using the communications equipment provided to the RPV units.

The feasibility of handing control of an air vehicle from one GCS to another was demonstrated in the advanced development program. However, no data will be available to provide an estimate of the probability of a successful handoff in an operational environment until OT II, currently scheduled for the second quarter of fiscal year 1985.

c. Vulnerability of Ground Systems

The independent sections are located within 5 to 10 kilometers of the zone of contact and are vulnerable to attack by enemy artillery and aircraft. The air vehicle launch and recovery operations may betray the locations of the ground systems. When displacing, a section provides a distinctive signature with a total of six 5-ton and two 1-1/4-ton trucks pulling three trailers.

With a rear area launch and recovery section the vulnerability to enemy action is reduced. The L/R section, with about 40 percent of the division RPV personnel and half of the trucks, is located in the rear area, 20 to 25 kilometers from the zone of contact. Its susceptibility to attack by enemy artillery and aircraft is greatly reduced. The operations section, while still located near the front, is much smaller and less likely to present a unique signature to the enemy either when deployed or when displacing. It has two 5-ton trucks, two 1-1/4-ton trucks, and two trailers.

d. Logistics and Maintenance

Logistics and maintenance are generally easier to accomplish in a division with rear area launch and recovery than in a division with independent sections.

Air vehicle losses can be more expeditiously replaced at one location in the rear than at four separate locations near the front. Similarly, maintenance of the air vehicles can be accomplished more efficiently at one central location.

Peacetime logistics and maintenance will also be simpler with rear area launch and recovery, since the division can carry a basic load of 13 air vehicles rather than the 20 currently planned or the 32 required for adequate sortie potential, for independent sections.

III. MANPOWER AND MAJOR EQUIPMENT REQUIREMENTS

While operational considerations are critical in choosing among alternative employment concepts, manpower and equipment requirements are also key elements. This chapter examines the manpower and equipment requirements of the RPV system for around-the-clock operations under the concepts of independent sections and rear area launch and recovery.

A. MANPOWER REQUIREMENTS

The manpower allocation for the daylight version of the RPV system is provided in the O&O concept. The manpower allocation for the 24-hour system has not been approved; however, the Materiel System Requirements Specification (MSRS) of September 1981 [Ref. 6] provides an allocation for costing purposes. Both of these documents provide the manning for an RPV platoon with four independent sections and a platoon headquarters. The MSRS shows, for 24-hour operation, a platoon headquarters with 3 people and 4 sections with 18 people each, for a total of 75 people in the platoon. In the Division '86 concept there would be 5 independent sections per division with no platoon headquarters, for a total of 90 people.

The functions performed in each independent section, as described in the O&O concept, can be divided into three categories: mission control, launch and recovery, and maintenance. Table 4 lists the manpower requirements for 24-hour operation shown in the MSRS.

In the rear area launch and recovery concept, the operations section would perform exactly the same functions as the mission control element of the independent section and would require the same maintenance support. The launch and recovery section would perform the same functions as the launch and recovery element of the independent section. In addition, it must

coordinate mission requirements with the operations sections and control the air vehicles to and from handoff with the operations sections. The launch and recovery section commander and section chief would perform the mission coordination function. Air vehicle operators on each of the L/R teams would control the air vehicles. Each team would require a power generator wheeled vehicle mechanic. The description of duties in the O&O concept and data in the Amended Provisional Qualitative and Quantitative Personnel Requirements Information (QQPRI) of 30 March 1979 indicate that one ground systems mechanic could support both L/R teams.

TABLE 4
MANPOWER REQUIREMENTS FOR AN INDEPENDENT SECTION

Mission Control			
RPV tech (section cdr.)	WO	211B	1
Section chief	E-7	13T40	1
Team leader	E-6	13T30	2
Sr. MPO	E-5	13T20	1
MPO	E-4	13T10	2
Sr. AVO	E-5	13T20	1
AVO	E-4	13T10	2
		Total	10
Launch and Recovery			
L/R team leader	E-5	13T20	1
AV mech	E-4	13T10 P9	1
AV mech	E-3	13T10 P9	1
RPV crewman	E-3	13T10	3
		Total	6
Maintenance			
Grd sys mech	E-5	13T20 P9	1
Pwr gen whl veh	E-4	63B10	1
		Total	2

The manpower requirements for the rear area launch and recovery concept (excluding the platoon headquarters), based on the allocation for independent sections in the MSRS, would be as shown in Table 5.

TABLE 5
MANPOWER REQUIREMENTS FOR REAR AREA
LAUNCH AND RECOVERY CONCEPT

OPERATIONS SECTION

Mission Control				
RPV tech (section cdr.)	WO	211B	1	
Section chief	E-7	13T40	1	
Team leader	E-6	13T30	2	
Sr. MPO	E-5	13T20	1	
Sr. AVO	E-5	13T20	1	
MPO	E-4	13T10	2	
AVO	E-4	13T10	2	
		Subtotal	10	
Maintenance				
Grd sys mech	E-5	13T20 P9	1	
Pwr gen whl veh mech	E-4	63B10	1	
		Subtotal	2	
		Section Total		12

LAUNCH AND RECOVERY SECTION

Mission Coordination				
RPV tech (section cdr.)	WO	211B	1	
Section chief	E-7	13T40	1	
		Subtotal	2	
Maintenance				
Grd Sys Mech	E-5	13T20 P9	1	
		Subtotal	1	
Launch and Recovery Team (2 per L/R section)				
Launch and Recovery				
Team leader	E-5	13T20	1	
AV mech	E-4	13T10 P9	1	
AV mech	E-3	13T10 P9	1	
RPV crewman	E-3	13T10	3	
		Subtotal	6	
Air Vehicle Control				
Sr. AVO	E-5	13T20	1	
AVO	E-4	13T10	2	
		Subtotal	3	
Maintenance				
Grd sys mech	E-5	13T20 P9	1	
		Subtotal	1	
		Section total		23

Shown below are the RPV manpower requirements, based on the allocation shown in the MSRS, for divisions with three, four, and five sections. The requirements for three and four sections include a platoon headquarters of three people. The requirements for five sections are based on the Division '86 concept with no platoon headquarters.

	Manpower Requirements	
Sections	Independent Sections	Rear Area Launch and Recovery
3	57	62
4	75	74
5	90	83

It is recognized in the O&O concept that the allocation of personnel to the RPV platoon is the minimum. It does not allow for physical security, KP, and other necessary services, indicating that these services will be supplied by the supported field artillery units.

The data available provide a basis for drawing only tentative conclusions about the manpower requirements for the concepts of independent sections and rear area launch and recovery. It appears that if a division has three RPV sections it will require slightly fewer personnel with independent sections, and with five RPV sections it would require slightly fewer with rear area launch and recovery. Manpower requirements do not appear to provide a strong basis for a choice between the two concepts.

B. MAJOR EQUIPMENT REQUIREMENTS

The O&O concept [Ref. 1] provides the allocation of major equipment approved for the daylight version of the RPV system. The MSRS [Ref. 3] provides the allocation for the 24-hour system shown in Table 6.

The major equipment required for a division with rear area launch nd recovery, extrapolated from the allocation provided in the MSRS, is shown in Table 7.

TABLE 6
MAJOR EQUIPMENT REQUIREMENTS
FOR A DIVISION WITH INDEPENDENT RPV SECTIONS

Platoon

- 1/4-ton truck
- 1/4-ton trailer

RPV Section (4)

- GCS mounted on 5-ton truck
- Launch subsystem mounted on 5-ton truck
- Recovery subsystem mounted on 5-ton truck
- AV handler mounted on 5-ton truck
- AV maintenance shelter mounted on 5-ton truck
- RGT mounted on 3/4-ton trailer, M116A1
- Truck, 5-ton, AV carrier (3 AVs)
- Truck, 1 1/4-ton
- Truck, 1 1/4-ton
- Generator, 30-kW, mounted on trailer, M200A1
- Generator, 30-kW, mounted on trailer, M200A1
- Theodolite, T-16 and survey set, FA

TABLE 7
MAJOR EQUIPMENT REQUIREMENTS
FOR A DIVISION WITH REAR AREA LAUNCH AND RECOVERY

Platoon

- 1/4-ton truck
- 1/4-ton trailer

Operations Section (4)

- GCS mounted on 5-ton truck
- RGT mounted on 3/4-ton trailer, M116A1
- Truck, 5-ton
- Truck, 1 1/4-ton
- Truck, 1 1/4-ton
- Generator, 30-kW, mounted on 5-ton truck
- Generator, 30-kW, mounted on trailer, M200A1
- Theodolite, T-16 and survey set, FA

Launch and Recovery Section

- Truck, 1 1/4-ton
- Truck, 5-ton, AV carrier (3 AVs)
- Truck, 5-ton, AV carrier (3 AVs)
- Truck, 5-ton, AV carrier (3 AVs)

L/R Team (2)

- GCS mounted on 5-ton truck
- Launch subsystem mounted on 5-ton truck
- Recovery subsystem mounted on 5-ton truck
- AV handler mounted on 5-ton truck
- Maintenance shelter mounted on 5-ton truck
- RGT mounted on 3/4-ton trailer, M116A1
- Truck, 1 1/4-ton
- Generator, 30-kW, mounted on trailer, M200A1
- Generator, 30-kW, mounted on trailer, M200A1
- Theodolite, T-16 and survey set, FA

Table 8 shows a comparison of the major equipment required for the two concepts in divisions with three, four, and five RPV sections. The divisions with three and four sections include the 1/4-ton truck and 1/4-ton trailer allocated to the platoon headquarters, while divisions with five sections do not.

Some preliminary calculations, based on The RPV Baseline Cost Estimate (BCE), February 1981, [Ref. 7] indicate that the costs associated with major equipment in a division with four RPV sections would be about the same for the two concepts. The equipment costs for a division with three independent sections would then be expected to be less than one with rear area launch and recovery and greater with five RPV sections. The cost differences do not appear sufficient to form a basis for choosing between the two concepts.

TABLE 8
COMPARISON OF MAJOR EQUIPMENT REQUIREMENTS
FOR REAR AREA LAUNCH AND RECOVERY AND INDEPENDENT SECTIONS

	3 Sections		4 Sections		5 Sections	
Equipment	RA L/R	Independent Sections	RA L/R	Independent Sections	RA L/R	Independent Sections
GCS	5	3	6	4	7	5
RGT	5	3	6	4	7	5
Launcher	2	3	2	4	2	5
Recovery system	2	3	2	4	2	5
Maintenance shelter	2	3	2	4	2	5
AV handler	2	3	2	4	2	5
Generator, 30-kW	10	6	12	8	14	10
Theodolite	5	3	6	4	7	5
1/4-ton truck	1	1	1	1	0	0
1 1/4-ton truck	9	6	11	8	13	10
5-ton truck	19	18	21	24	23	30
M116A1 trailer	5	3	6	4	7	5
M200A1 trailer	7	6	8	8	9	10
1/4-ton trailer	1	1	1	1	0	0
Basic Load Air Vehicles	13	15	13	20	13	25

Appendix A
ESTIMATES OF SORTIE LOSS RATES AND MISSION AND CYCLE TIMES

A. INTRODUCTION

This appendix develops estimates of per-sortie loss rates, mission times, and cycle times using the same basic procedures that were used in System Planning Corporation report 535, Control of Multiple Remotely Piloted Vehicles, December 1979 [Ref. 5]. It lists the possible outcomes of a sortie attempt and derives the probability and time associated with each event based on the assumptions stated in the body of the report and those listed below. Some explicit operational assumptions are listed in Table A-1.

TABLE A-1
OPERATIONAL ASSUMPTIONS

- Each sortie is planned for 3 hours - launch to recovery.
- The GCS/RGT must operate with the AV for 5 minutes before launch.
- AV preparation time on the launcher before GCS/RGT lockup with the AV is 25 minutes.
- The launcher is immediately reloaded after launch.
- Five minutes is required to unload and reload the launcher.
- Five minutes is required to unload the recovery system.
- Mission time is considered to be all time over enemy territory.
- Time to repair a ground system failure is 45 minutes for an independent section or an operations section and 42 minutes for an L/R section.
- A handoff attempt requires 5 minutes.
- Displacement requires 2.0 hours, including travel time.
- A system failure or air vehicle kill is equally likely in any two periods of equal time of exposure.

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TABLE A-1
OPERATIONAL ASSUMPTIONS (Continued)

- GCS failure results in the loss of the AV it is controlling in flight.
- AV failure while the AV is flying results in loss of the AV.
- Handoffs occur at the FLOT.
- If the L/R section and the operations section are exchanging air vehicles, a failed handoff attempt results in a lost AV. If only one AV is being handed off and the first attempt fails, a second attempt will be made.
- If a sensor failure occurs during climbout and transit when an AV exchange is planned, the handoff will be accomplished and the operations section will hold the AV with the failed sensor until the incoming AV is recovered; then the operations section will hand it back to the L/R section for recovery.
- Each independent section or L/R section accomplishes its own resupply.
- The independent sections or the operations sections are located with the supported field artillery units and will displace with them. However, they will not displace while they have an AV in the air. The units will displace three times in 24 hours. The L/R section will displace once a day with one L/R team displacing at a time.

With independent sections the probabilities derive primarily from the reliability of the elements of the RPV system and the vulnerability of the air vehicle to enemy defenses. The reliability values used here are the minimum acceptable values stated in the RPV Required Operational Capability (ROC) and incorporated in the full-scale development contract. In two instances, where MAV were not stated, it was necessary to assume reliability values. The reliability values used in this study are listed in Table A-2. The vulnerability of the air vehicle to enemy defenses has not yet been evaluated. However, there seems to be a consensus that the probability that an air vehicle will survive the planned 160-minute mission is about 0.75. This value is used as the basic value in this appendix; however, values of 0.90 and 1.00 are also considered for an independent section. The latter is included to show the expected losses due to reliability alone.

TABLE A-2
RPV SYSTEM RELIABILITY ASSUMPTIONS

Minimum Acceptable Values from the FSD Contract

P(successful 3-hour flight - less payload)	= .91
P(successful 3-hour flight with payload - less launch and recovery)	= .82
P(GCS and RGT complete 10 hours of continuous operations)	= .92
P(successful launch)	= .99

Values Not Provided in FSD Contract, But Assumed for This Study

P(successful recovery)	= .99
P(successful prelaunch)	= .99

Values Computed Assuming Equal Probability of Failure in Any Two Periods of Equal Length

P(successful 3-hour flight - less launch, recovery, and payload)	= .9285
P(successful 3-hour payload operation)	= .8832
P(successful 3-hour AV operation)	= .9520
P(GCS and RGT complete 3 hours continuous operation)	= .9753
P(successful 150-minute mission)	= .8383
P(successful 145-minute mission)	= .8523
P(successful 10-minute transit)	= .9890
P(successful 5-minute transit)	= .9945
P(successful 10-minute transit - AV and GCS)	= .9959

With rear area launch and recovery, a new event is introduced: air vehicle handoff between the launch and recovery section and the operations section. The probability of a successful handoff in a single attempt (P_h) has not been determined. It is believed that it will be high, on the order of 0.99. This value is given primary emphasis; however, the probabilities associated with sortie outcomes are also tabulated for P_h = 0.90 and 0.75.

B. INDEPENDENT SECTIONS

The possible outcomes of a sortie attempt by an independent section and the associated probabilities are shown in Table A-3 for probability of survival of enemy defenses (P_s) equal to 0.75, 0.90, and 1.00. The probability of air vehicle loss (P_l) on a sortie is also shown. The values in Table A-3 are computed to four decimal places so that the small probabil-

TABLE A-3
PROBABILITIES OF EVENTS - INDEPENDENT RPV SECTION

Event	P_s=1.00	P_s=0.90	P_s=0.75
Successful Mission			
- AV recovered	.8000	.7200	.6000
- AV lost on recovery	.0081	.0073	.0061
- AV lost in transit - AV	.0029	.0026	.0022
- AV lost in transit - GCS	.0015	.0014	.0011
Mission Failure			
- AV failure	.0392	.0353	.0294
- Sensor failure			
o AV recovered	.0957	.0861	.0718
o AV lost on recovery	.0010	.0009	.0008
o AV lost in transit - AV	.0003	.0003	.0002
o AV lost in transit - GCS	.0002	.0002	.0001
- GCS failure	.0204	.0184	.0153
AV Killed	.0000	.0969	.2423
Climbout/Transit Failure			
- AV	.0027	.0027	.0027
- Sensor	.0067	.0067	.0067
- GCS	.0014	.0014	.0014
Launcher Failure	.0099	.0099	.0099
Prelaunch Failure			
- AV or sensor	.0087	.0087	.0087
- GCS	.0013	.0013	.0013
AV Recovered	.9223	.8327	.6984
AV Lost (P_l)	.0777	.1673	.3016

ities of some possible events will be shown. This should not be construed as an implication that this degree of precision is warranted by the underlying assumptions. The possible outcomes of a sortie attempt and the associated times are shown in Table A-4. Mission time (T_m) is the time spent over the mission area. Replacement time (T_r) is the time between the end of mission time for one air vehicle and the start of mission time for the next. The expected mission time and replacement time per sortie are also shown. They are derived by weighting the outcome time by the outcome probability and summing for all possible outcomes. Cycle time (T_c) is the time between the beginning of mission time for two successive air vehicles and is the sum of mission time and replacement time.

C. REAR AREA LAUNCH AND RECOVERY

1. Four Sortie Plans

The air vehicle handoff with rear area launch and recovery produces four different sortie patterns with different probabilities and times. The basic sortie plan is that the launch and recovery section will launch an air vehicle to replace one that the operations section is returning after it has completed its mission time. In this case, there is an exchange of air vehicles at handoff--called a two-way handoff in this report. The handoffs will be called two-way out for the air vehicle just launched and two-way back for the air vehicle that has completed its mission time and is being recovered. When the operations section has no air vehicle to return, that is, on the first sortie after displacement or when its air vehicle was lost during the mission, the handoff will be one-way out. Similarly, when the operations section is returning an air vehicle for recovery before displacing, the handoff will be one-way back. Sortie planning then, will be based on the planned handoff pattern: one-way out, one-way back (1/1); one-way out, two-way back (1/2); two-way out, one-way back (2/1); and two-way out, two-way back (2/2).

TABLE A-4
EXPECTED TIMES - INDEPENDENT SECTIONS

Event	Mission Time (T_m)	Replacement Time (T_r)
Successful Mission		
- AV recovered	160	25
- AV lost on recovery	160	25
- AV lost in transit - AV	160	17.5
- AV lost in transit - GCS	160	62.5
Mission Failure		
- AV	77.7	15
- Sensor		
o AV recovered	77.7	30
o AV lost on recovery	77.7	30
o AV lost in transit - AV	77.7	22.5
o AV lost in transit - GCS	77.7	67.5
- GCS	77.7	60
AV Killed	76.2[a]	15
Climbout/Transit Failure		
- AV	0	55
- Sensor	0	55
- GCS	0	80
Launcher Failure	0	100
Prelaunch Failure		
- AV or sensor	0	5
- GCS	0	72.5
$P_s = 1.00$	142.18	27.00
$P_s = 0.90$	135.60	25.95
$P_s = 0.75$	125.12	24.37

[a]This is the value when $P_s = 0.75$; for $P_s = 0.90$ it is 78.6.

The four possible sortie plans with associated probabilities and times must be combined to yield expected values of P_1 and T_m. There are delay times that are part of T_c, but they are not included in the list of possible sortie outcomes. In this section, all sources of delay are identified and estimated, a method for averaging the four sortie plans is devised, and estimates of P_1, T_m, and T_c are derived.

The possible outcomes of a sortie attempt by a rear area launch and recovery section and the associated probabilities for each of the four sortie plans are shown in Table A-5 for the case when $P_s = 0.77$ and $P_h = 0.99$. This value of P_s is computed for a planned 145-minute mission based on an assumed value of $P_s = 0.75$ for a planned 150-minute mission. Outcome probability values for the cases when $P_h = 0.90$ and 0.75 are given in Tables A-6 and A-7. Also shown in each table are the resulting values of P_1 and the probability that the air vehicle will reach the mission area and return to the handoff area for recovery (P_r). Again, the values in Tables A-5, A-6, and A-7 are computed to four decimal places to show the small probabilities of some possible events, but this does not imply the same degree of precision in the underlying assumptions.

The possible outcomes of a sortie attempt and the associated mission and delay times for the same cases are tabulated in Tables A-8 through A-10. The expected mission times and delay times (T_m, T_d) per sortie are also shown. Both mission time and delay times are affected by the value of P_h, since two attempts can be made on a one-way handoff while only one attempt is possible on a two-way handoff. The effects of handoff time are included in the times shown with each possible outcome in the tables. It is assumed that a handoff attempt requires 5 minutes. When a one-way handoff occurs, a second attempt can be made if the first is not successful. The expected time to accomplish a one-way handoff is dependent on P_h and is equal to $5 P_h + 10 P_h (1 - P_h)$. For selected values of P_h, the expected handoff time is as follows:

P_h	Expected Handoff Time
.99	5.05
.90	5.40
.75	5.63

TABLE A-5
REAR AREA LAUNCH AND RECOVERY:
POSSIBLE OUTCOMES AND PROBABILITIES
$P_s = 0.77$, $P_h = 0.99$

Outcome	Sortie Pattern 1/1	1/2	2/1	2/2
Successful Mission				
- AV recovered	.6221	.6160	.6160	.6099
- AV lost on recovery	.0063	.0063	.0063	.0062
- AV lost in transit - AV	.0046	.0046	.0046	.0045
- AV lost in transit - GCS	.0024	.0024	.0024	.0023
- AV lost on handoff	.0001	.0064	.0001	.0063
Mission Failure				
- AV failure	.0276	.0276	.0273	.0273
- GCS failure	.0143	.0143	.0142	.0142
- Sensor failure				
o AV recovered	.0668	.0662	.0662	.0655
o AV lost on recovery	.0007	.0007	.0007	.0007
o AV lost in transit - AV	.0005	.0005	.0005	.0005
o AV lost in transit - GCS	.0003	.0003	.0003	.0003
o AV lost on handoff	.0000	.0007	.0000	.0007
AV Killed	.2227	.2227	.2205	.2205
Sensor Failure In Transit				
- AV recovered	.0066	.0066	.0065	.0065
- AV lost on recovery	.0001	.0001	.0001	.0001
- AV lost on handoff	.0000	.0000	.0000	.0000
Failed Handoff				
- AV recovered	.0001	.0001	.0000	.0000
- AV lost on recovery	.0000	.0000	.0000	.0000
- AV lost in transit - AV	.0000	.0000	.0000	.0000
- AV lost in transit - GCS	.0000	.0000	.0000	.0000
- AV lost on handoff	.0000	.0000	.0098	.0098
Climbout/Transit Failure				
- AV	.0027	.0027	.0027	.0027
- GCS	.0014	.0014	.0014	.0014
Launcher Failure	.0099	.0099	.0099	.0099
Prelaunch Failure				
- AV or Sensor	.0087	.0087	.0087	.0087
- GCS	.0013	.0013	.0013	.0013
P_l	.2837	.2907	.2909	.2975
P_r	.7038	.7038	.6971	.6969

TABLE A-6
REAR AREA LAUNCH AND RECOVERY:
POSSIBLE OUTCOMES AND PROBABILITIES
$P_s = 0.77$, $P_h = 0.90$

Outcome	Sortie Pattern 1/1	1/2	2/1	2/2
Successful Mission				
- AV recovered	.6099	.5544	.5544	.5040
- AV lost on recovery	.0062	.0056	.0056	.0051
- AV lost in transit - AV	.0045	.0041	.0041	.0037
- AV lost in transit - GCS	.0023	.0021	.0021	.0019
- AV lost on handoff	.0063	.0629	.0057	.0572
Mission Failure				
- AV	.0273	.0273	.0248	.0248
- GCS	.0142	.0142	.0129	.0129
- Sensor				
o AV recovered	.0655	.0596	.0596	.0541
o AV lost on recovery	.0007	.0006	.0006	.0006
o AV lost in transit - AV	.0005	.0004	.0004	.0004
o AV lost in transit - GCS	.0003	.0003	.0003	.0002
o AV lost on handoff	.0007	.0068	.0006	.0061
AV Killed	.2205	.2205	.2004	.2004
Sensor Failure In Transit				
- AV recovered	.0066	.0066	.0059	.0059
- AV lost on recovery	.0001	.0001	.0001	.0001
- AV lost on handoff	.0000	.0000	.0001	.0001
Failed Handoff				
- AV recovered	.0095	.0095	.0000	.0000
- AV lost on recovery	.0001	.0001	.0000	.0000
- AV lost in transit - AV	.0000	.0000	.0000	.0000
- AV lost in transit - GCS	.0000	.0000	.0000	.0000
- AV lost on handoff	.0000	.0000	.0975	.0975
Climbout/Transit Failure				
- AV	.0027	.0027	.0027	.0027
- GCS	.0014	.0014	.0014	.0014
Launcher Failure	.0099	.0099	.0099	.0099
Prelaunch Failure				
- AV or Sensor	.0087	.0087	.0087	.0087
- GCS	.0013	.0013	.0013	.0013
P_l	.2871	.3491	.3593	.4151
P_r	.6969	.6968	.6334	.6333

TABLE A-7
REAR AREA LAUNCH AND RECOVERY:
POSSIBLE OUTCOMES AND PROBABILITIES
$P_s = 0.77$, $P_h = 0.75$

Outcome	Sortie Pattern 1/1	1/2	2/1	2/2
Successful Mission				
- AV recovered	.5469	.4375	.4375	.3500
- AV lost on recovery	.0055	.0044	.0044	.0036
- AV lost in transit - AV	.0041	.0032	.0032	.0026
- AV lost in transit - GCS	.0021	.0017	.0017	.0013
- AV lost on handoff	.0372	.1489	.0298	.1192
Mission Failure				
- AV	.0258	.0258	.0207	.0207
- GCS	.0134	.0134	.0107	.0107
- Sensor				
o AV recovered	.0587	.0470	.0470	.0375
o AV lost on recovery	.0006	.0005	.0005	.0004
o AV lost in transit - AV	.0004	.0003	.0003	.0003
o AV lost in transit - GCS	.0003	.0002	.0002	.0002
o AV lost on handoff	.0040	.0160	.0032	.0128
AV Killed	.2088	.2088	.1670	.1670
Sensor Failure In Transit				
- AV recovered	.0066	.0066	.0046	.0046
- AV lost on recovery	.0001	.0001	.0001	.0001
- AV lost on handoff	.0000	.0000	.0003	.0003
Failed Handoff				
- AV recovered	.0597	.0597	.0000	.0000
- AV lost on recovery	.0006	.0006	.0000	.0000
- AV lost in transit - AV	.0002	.0002	.0000	.0000
- AV lost in transit - GCS	.0001	.0001	.0000	.0000
- AV lost on handoff	.0000	.0000	.2438	.2438
Climbout/Transit Failure				
- AV	.0027	.0027	.0027	.0027
- GCS	.0014	.0014	.0014	.0014
Launcher Failure	.0099	.0099	.0099	.0099
Prelaunch Failure				
- AV or Sensor	.0087	.0087	.0087	.0087
- GCS	.0013	.0013	.0013	.0013
P_l	.3073	.4283	.4900	.5871
P_r	.6598	.6597	.5278	.5280

Two sources of delay are not shown in the tables: the handoff time on the first sortie after displacement and the delay caused by two launch and recovery teams serving more than two operations sections. These delays are discussed below.

a. First Sortie Delay

On the first sortie after displacement the operations section starts operations with a handoff from the launch and recovery section. This period of non-mission time is not accounted for in the computations of replacement times above. The expected time per sortie attributable to the first sortie handoff (T_f) is found by dividing the handoff time by the expected number of sorties between displacements.

b. Queue Delay

The delay times in Tables A-8 through A-10 are computed assuming that there are no occasions when an operations section would have to wait for service because the launch and recovery section was fully occupied with other operations sections. The assumed operational procedures were designed to eliminate or greatly reduce the occasions when an operations section would experience delay in handing off an air vehicle that had completed its mission time. Priority is given to recovering an air vehicle from the operations section over launching a new one.

However, the operations sections can expect delays in getting a requested launch. The probability of such a delay and the length of the delay, given that one occurs, are derived by queueing theory. The probability that an operations section can expect a wait for service from the launch and recovery section is a function of the number of operations sections, the frequency of requests for service, the number of launch and recovery teams, and the length of time it takes to provide the service. Queue delay is derived for four and five operational sections serviced by one and two launch and recovery teams. The operations sections displace three times a day and the launch teams displace once a day. In a period of

TABLE A-8
REAR AREA LAUNCH AND RECOVERY EXPECTED TIMES
$P_s = 0.77,\ P_h = 0.99$

Outcome	Sortie Pattern 1/1 T_m	1/1 T_d	1/2 T_m	1/2 T_d	2/1 T_m	2/1 T_d	2/2 T_m	2/2 T_d
Successful Mission								
- AV recovered	144.9	5.05	144.95	5.0	144.95	5.05	145.0	5.0
- AV lost on recovery	144.9	5.05	144.95	5.0	144.95	5.05	145.0	5.0
- AV lost in transit - AV	144.9	5.05	144.95	5.0	144.95	5.05	145.0	5.0
- AV lost in transit - GCS	144.9	5.05	144.95	5.0	144.95	5.05	145.0	5.0
- AV lost on handoff	144.9	5.05	144.95	5.0	144.94	5.05	145.0	5.0
Mission Failure								
- AV	70.6	0.0	70.6	30.05	70.6	0.0	70.6	30.05
- GCS	70.6	0.0	70.6	55.05	70.6	0.0	70.6	55.05
- Sensor								
o AV recovered	70.6	10.05	70.6	25.05	70.6	10.05	70.6	25.0
o AV lost on recovery	70.6	10.05	70.6	25.0	70.6	10.05	70.6	25.0
o AV lost in transit - AV	70.6	10.05	70.6	25.0	70.6	10.05	70.6	25.0
o AV lost in transit - GCS	70.6	10.05	70.6	25.0	70.6	10.05	70.6	25.0
o AV lost on handoff	70.6	10.05	70.6	25.0	70.6	10.05	70.6	25.0
AV Killed	69.3	0.0	69.3	30.05	69.3	0.0	69.3	30.05
Sensor Failure In Transit								
- AV recovered	0.0	30.0	0.0	30.0	0.0	60.1	0.0	60.1
- AV lost on recovery	0.0	30.0	0.0	30.0	0.0	60.1	0.0	60.1
- AV lost on handoff	-	-	-	-	0.0	45.1	0.0	45.1
Failed Handoff								
- AV recovered	0.0	35.05	0.0	35.05	-	-	-	-
- AV lost on recovery	0.0	35.05	0.0	35.05	-	-	-	-
- AV lost in transit - AV	0.0	30.0	0.0	30.0	-	-	-	-
- AV lost in transit - GCS	0.0	69.05	0.0	67.05	-	-	-	-
- AV lost on handoff	-	-	-	-	0.0	40.05	0.0	40.05
Climbout/Transit Failure								
- AV	0.0	30.00	0.0	30.0	0.0	40.1	0.0	40.1
- GCS	0.0	52.0	0.0	52.0	0.0	57.5	0.0	57.5
Launcher Failure	0.0	72.5	0.0	72.5	0.0	77.5	0.0	77.5
Prelaunch Failure								
- AV or Sensor	0.0	5.0	0.0	5.0	0.0	5.0	0.0	5.0
- GCS	0.0	44.5	0.0	44.5	0.0	49.5	0.0	49.5
Expected Times	115.38	5.02	115.41	13.00	114.24	5.71	114.25	13.61

TABLE A-9
REAR AREA LAUNCH AND RECOVERY EXPECTED TIMES
$P_s = 0.77,\ P_h = 0.90$

Outcome	Sortie Pattern 1/1		1/2		2/1		2/2	
	T_m	T_d	T_m	T_d	T_m	T_d	T_m	T_d
Successful Mission								
- AV recovered	144.2	5.4	144.6	5.0	144.6	5.4	145.0	5.0
- AV lost on recovery	144.2	5.4	144.6	5.0	144.6	5.4	145.0	5.0
- AV lost in transit - AV	144.2	5.4	144.6	5.0	144.6	5.4	145.0	5.0
- AV lost in transit - GCS	144.2	5.4	144.6	5.0	144.6	5.4	145.0	5.0
- AV lost on handoff	144.2	5.4	144.6	5.0	144.6	5.4	145.0	5.0
Mission Failure								
- AV	70.2	0.0	70.4	30.4	70.4	0.0	70.6	30.4
- GCS	70.2	0.0	70.4	55.4	70.4	0.0	70.6	55.4
- Sensor								
o AV recovered	70.2	10.4	70.4	25.0	70.4	10.4	70.6	25.0
o AV lost on recovery	70.2	10.4	70.4	25.0	70.4	10.4	70.6	25.0
o AV lost in transit - AV	70.2	10.4	70.4	25.0	70.4	10.4	70.6	25.0
o AV lost in transit - GCS	70.2	10.4	70.4	25.0	70.4	10.4	70.6	25.0
o AV lost on handoff	70.2	10.4	70.4	25.0	70.4	10.4	70.6	25.0
AV Killed	69.0	0.0	69.2	30.4	69.2	0.0	69.3	30.4
Sensor Failure In Transit								
- AV recovered	0.0	30.0	0.0	30.0	0.0	60.8	0.0	60.8
- AV lost on recovery	0.0	30.0	0.0	30.0	0.0	60.8	0.0	60.8
- AV lost on handoff	-	-	-	-	0.0	45.8	0.0	45.8
Failed Handoff								
- AV recovered	0.0	35.4	0.0	35.4	-	-	-	-
- AV lost on recovery	0.0	35.4	0.0	35.4	-	-	-	-
- AV lost in transit - AV	0.0	30.0	0.0	30.0	-	-	-	-
- AV lost in transit - GCS	0.0	67.4	0.0	67.4	-	-	-	-
- AV lost on handoff	-	-	-	-	0.0	40.4	0.0	40.4
Climbout/Transit Failure								
- AV	0.0	30.0	0.0	30.0	0.0	40.8	0.0	40.8
- GCS	0.0	52.0	0.0	52.0	0.0	57.4	0.0	57.4
Launcher Failure	0.0	72.0	0.0	72.0	0.0	77.4	0.0	77.4
Prelaunch Failure								
- AV or Sensor	0.0	5.0	0.0	5.0	0.0	5.0	0.0	5.0
- GCS	0.0	44.5	0.0	44.5	0.0	49.9	0.0	49.9
Expected Times	113.61	5.57	113.91	13.32	103.55	9.10	103.82	16.61

TABLE A-10
REAR AREA LAUNCH AND RECOVERY EXPECTED TIMES
$P_s = 0.77$, $P_h = 0.75$

Outcome	Sortie Pattern 1/1		1/2		2/1		2/2	
	T_m	T_d	T_m	T_d	T_m	T_d	T_m	T_d
Successful Mission								
- AV recovered	143.8	5.6	144.4	5.0	144.4	5.6	145.0	5.0
- AV lost on recovery	143.8	5.6	144.4	5.0	144.4	5.6	145.0	5.0
- AV lost in transit - AV	143.8	5.6	144.4	5.0	144.4	5.6	145.0	5.0
- AV lost in transit - GCS	143.8	5.6	144.4	5.0	144.4	5.6	145.0	5.0
- AV lost on handoff	143.8	5.6	144.4	5.0	144.4	5.6	145.0	5.0
Mission Failure								
- AV	70.0	0.0	70.3	30.6	70.3	0.0	70.6	30.6
- GCS	70.0	0.0	70.3	55.6	70.3	0.0	70.6	55.6
- Sensor								
o AV recovered	70.0	10.6	70.3	25.0	70.3	10.6	70.6	25.0
o AV lost on recovery	70.0	10.6	70.3	25.0	70.3	10.6	70.6	25.0
o AV lost in transit - AV	70.0	10.6	70.3	25.0	70.3	10.6	70.6	25.0
o AV lost in transit - GCS	70.0	10.6	70.3	25.0	70.3	10.6	70.6	25.0
o AV lost on handoff	70.0	10.6	70.3	25.0	70.3	10.6	70.6	25.0
AV Killed	68.8	0.0	69.1	30.6	69.1	0.0	69.3	30.6
Sensor Failure In Transit								
- AV recovered	0.0	30.0	0.0	30.0	0.0	61.2	0.0	61.2
- AV lost on recovery	0.0	30.0	0.0	30.0	0.0	61.2	0.0	61.2
- AV lost on handoff	-	-	-	-	0.0	46.2	0.0	46.2
Failed Handoff								
- AV recovered	0.0	35.6	0.0	35.6	-	-	-	-
- AV lost on recovery	0.0	35.6	0.0	35.6	-	-	-	-
- AV lost in transit - AV	0.0	30.0	0.0	30.0	-	-	-	-
- AV lost in transit - GCS	0.0	67.4	0.0	67.4	-	-	-	-
- AV lost on handoff	-	-	-	-	0.0	40.6	0.0	40.6
Climbout/Transit Failure								
- AV	0.0	30.0	0.0	30.0	0.0	41.2	0.0	41.2
- GCS	0.0	52.0	0.0	52.0	0.0	57.6	0.0	57.6
Launcher Failure	0.0	72.0	0.0	72.0	0.0	77.6	0.0	77.6
Prelaunch Failure								
- AV or Sensor	0.0	5.0	0.0	5.0	0.0	5.0	0.0	5.0
- GCS	0.0	44.5	0.0	44.5	0.0	49.9	0.0	49.9
Expected Times	107.27	7.34	107.70	15.83	86.17	14.48	86.51	21.27

24 hours, there will be 4 hours when the operations sections are serviced by only one launch and recovery team.

The frequency of requests for service is a function of the number of operations sections and the per-sortie cycle time (T_c). Under the stated assumptions the launch and recovery per-sortie service time is found to be approximately 35 minutes.

The probability of a wait for service is shown in Figure A-1 as a function of the expected time between sortie requests for four and five operations sections with one and two launch and recovery teams. Figure A-2 shows the expected waiting time, given that a wait occurs, and Figure A-3 shows the expected per-sortie waiting time (T_q).

FIGURE A-1

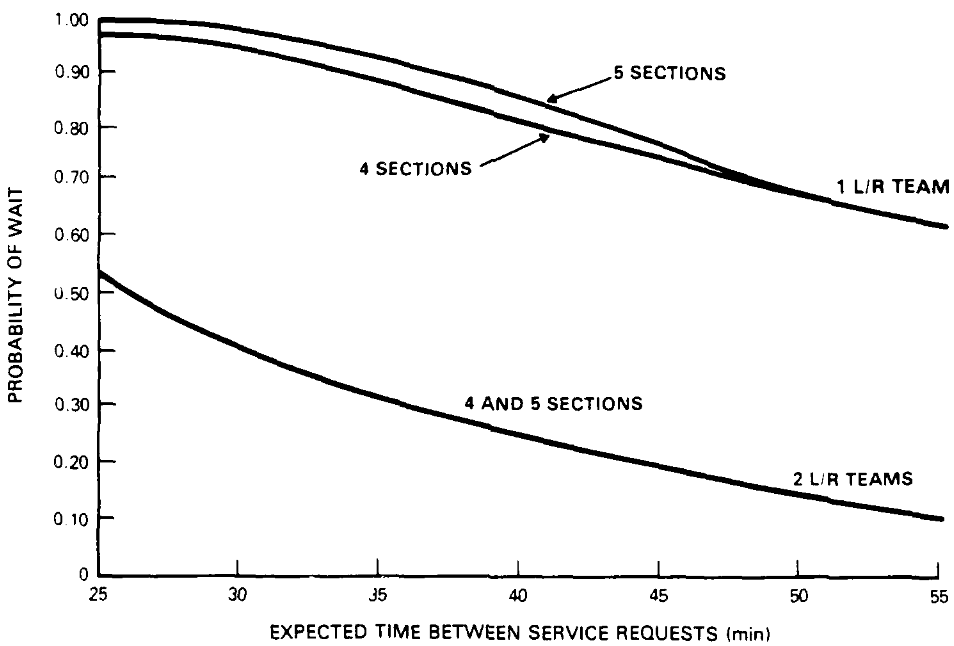

FIGURE A-1
PROBABILITY OF A WAIT FOR SERVICE

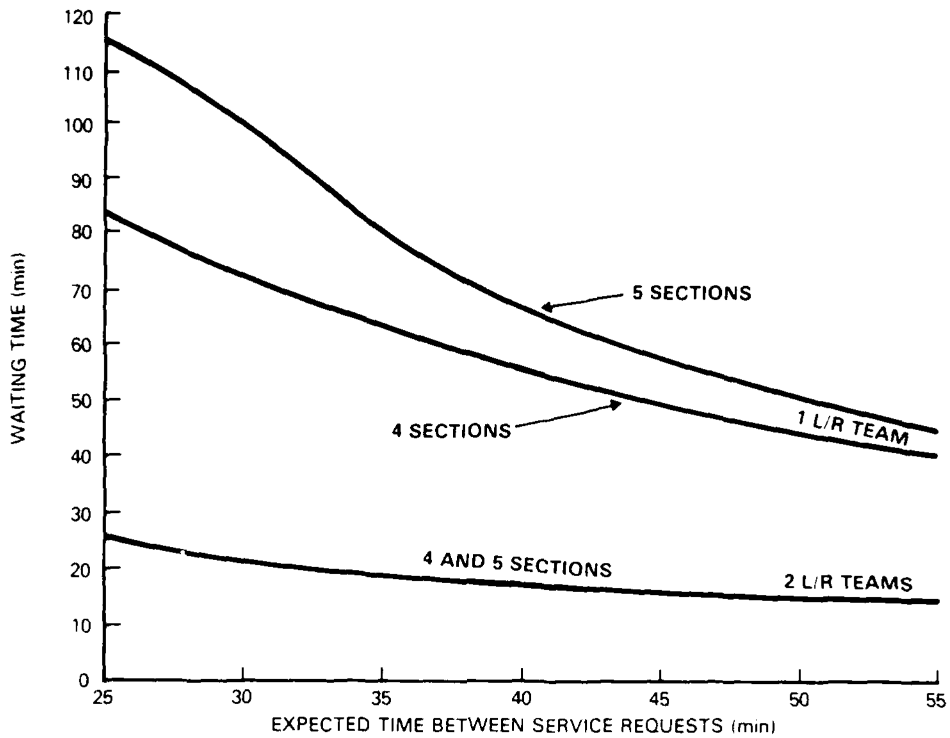

FIGURE A-2
EXPECTED WAITING TIME WHEN A WAIT OCCURS

In a surge situation, a division with four operations sections would expect a queue delay of about 18 minutes on about one out of six sorties when two launch and recovery teams were in operation. When one launch and recovery team was displacing, the expected delay would be about 45 minutes on about two out of three sorties. With five operations sections the expected queue delays would be about 20 minutes on about one-fourth of the sorties with two launch and recovery teams and about 60 minutes on about three-fourths of the sorties with one launch and recovery team.

2. Per-Sortie Estimates

A proper set of weights for combining the four sortie plans into a single estimate would be the proportion of the time each is used. The period between displacements provides a convenient means for estimating the use of the four possible sortie plans. The first sortie after displacement

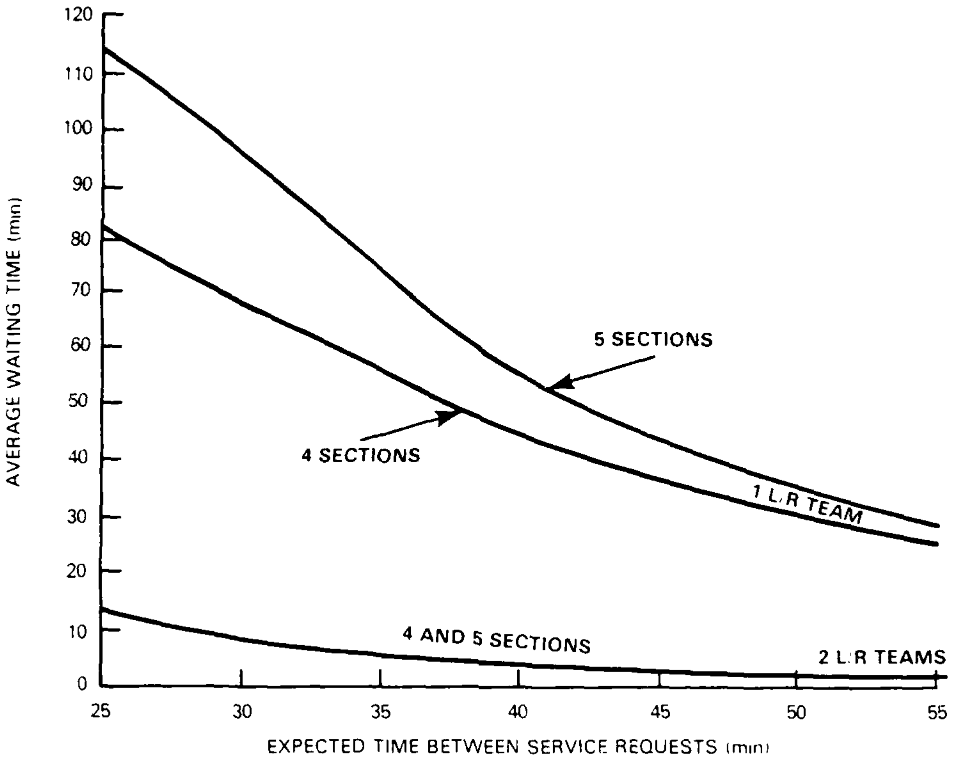

FIGURE A-3
AVERAGE WAITING TIME PER SORTIE

will be planned one-way out, two-way back (1/2). The last sortie before displacement will be planned 1/1 or 2/1 depending on the outcome of the previous sortie. The intervening sorties will be planned 2/2 if the previous sortie returns from the mission area and 1/2 if it does not. The probability that an air vehicle will return from the mission area (P_r) has been shown in Tables A-5 through A-7.

If the expected number of sorties between displacements is S, the expected proportion of the time each sortie plan is used is as follows:

Sortie Plan:	1/1	1/2	2/1	2/2
Weight:	$\frac{1-P_r}{S}$	$\frac{1+(S-2)(1-P_r)}{S}$	$\frac{P_r}{S}$	$\frac{(S-2)P_r}{S}$

The four possible sortie plans may have different values for P_r and S. In addition, S is a function of T_c, which has not yet been determined. The process of deriving weights and estimating T_c is an iterative one starting with estimates of P_r and T_c.

The estimates for the case when $P_s = 0.77$ and $P_h = 0.99$ are shown in Table A-11 for divisions with three, four, and five operations sections engaged in normal surge operations with one and two launch and recovery teams and for a period of 8 hours of all-out effort when no displacement takes place. Tables A-12 and A-13 contain similar estimates for the cases when $P_h = 0.90$ and 0.75.

TABLE A-11
SORTIE LOSS RATES AND TIMES FOR
$P_s = 0.77$, $P_h = 0.99$

Time in minutes

	T_m	T_d	T_f	T_q	T_c	T_m/T_c	P_l
3 Operations Sections							
Normal, 2 L/R	115	10	2	2	129	.89	.29
Normal, 1 L/R	115	10	2	12	139	.83	.29
All-out effort	115	11	1	3	130	.88	.29
4 Operations Sections							
Normal, 2 L/R	115	11	2	3	131	.88	.29
Normal, 1 L/R	115	10	2	29	156	.74	.29
All-out effort	115	11	1	6	133	.86	.29
5 Operations Sections							
Normal, 2 L/R	115	11	2	5	133	.86	.29
Normal, 1 L/R	115	10	2	43	170	.68	.29
All-out effort	115	11	1	10	137	.84	.29

TABLE A-12
SORTIE LOSS RATES AND TIMES FOR
$P_s = 0.77, \quad P_h = 0.90$

Time in minutes

	T_m	T_d	T_f	T_q	T_c	T_m/T_c	P_1
3 Operations Sections							
Normal, 2 L/R	110	12	2	2	126	.87	.36
Normal, 1 L/R	110	11	2	13	136	.81	.36
All-out effort	109	12	1	4	126	.87	.37
4 Operations Sections							
Normal, 2 L/R	110	11	2	4	127	.87	.36
Normal, 1 L/R	110	11	2	30	153	.72	.35
All-out effort	109	12	1	7	129	.85	.36
5 Operations Sections							
Normal, 2 L/R	110	11	2	6	129	.85	.36
Normal, 1 L/R	110	11	2	45	168	.65	.35
All-out effort	109	13	1	11	134	.81	.36

TABLE A-13
SORTIE LOSS RATES AND TIMES FOR
$P_s = 0.77$, $P_h = 0.75$

Time in minutes

	T_m	T_d	T_f	T_q	T_c	T_m/T_c	P_1
3 Operations Sections							
Normal, 2 L/R	99	16	2	2	119	.83	.46
Normal, 1 L/R	100	15	2	14	130	.76	.45
All-out effort	98	16	1	4	119	.82	.48
4 Operations Sections							
Normal, 2 L/R	99	16	2	4	121	.82	.46
Normal, 1 L/R	101	15	2	31	148	.68	.44
All-out effort	98	16	1	8	123	.80	.47
5 Operations Sections							
Normal, 2 L/R	99	14	2	7	124	.80	.45
Normal, 1 L/R	101	14	2	47	164	.62	.43
All-out effort	98	17	1	12	128	.77	.47

Appendix B

SORTIE POTENTIAL

A. INTRODUCTION

In any battle situation it is important that the RPV unit be able to support its associated field artillery unit with a sortie over the mission area whenever it is needed. The most rigorous requirements are present in a surge situation when continuous support is required and the RPV unit must maintain an air vehicle in the mission area the maximum possible amount of time. The sortie potential of an RPV unit may be defined as its capability to mount the maximum expected number of sorties in a given period of time. Sortie potential can be quantified as the probability that the maximum expected number of sorties in a given period can be accomplished with the number of air vehicles available. This probability depends on the operational time available during the period, the expected number of sorties, the per-sortie loss rate, and the number of air vehicles available. These parameters are discussed in the following paragraphs.

B. OPERATIONAL TIME

In a surge situation the RPV section will launch one sortie after another, interrupted only by the requirement to displace. If an all-out effort is being made so that no displacement takes place, 100 percent of the period is operational time. Under the normal surge conditions assumed for this study the section will spend 6 hours of each 24 in displacing. Therefore, the expected operational time in any given period is 75 percent of the period, when the section is capable of 24-hour-per-day operation.

The operational time for daylight-only operation with the TV sensor depends on the number of hours of daylight. In Europe, there are about 16

hours of daylight in the summer months and about 8 hours of daylight in the winter months. Based on the previous assumption of a requirement to displace three times a day, the assumptions made with regard to displacement during daylight hours and the resulting available operational hours are shown below:

Hours of Daylight	Displacements During Daylight	Available Operational Hours
8	0	8
12	1	10
16	2	12

C. EXPECTED NUMBER OF SORTIES

Under the assumption of a surge situation, the maximum expected number of sorties (S) in any given period is determined by dividing the operational time in the period by the expected cycle time (T_c) for one sortie. T_c is a function of air vehicle flight time and RPV system reliability and survivability and is derived in Appendix A.

D. AIR VEHICLES LOSS RATES

The expected air vehicle loss rate (P_1) is a function of air vehicle flight time and RPV system reliability and survivability and is derived in Appendix A.

E. AIR VEHICLES AVAILABLE

It is assumed that the RPV element will possess its basic load of air vehicles at the start of a surge operation. The number of air vehicles available at a later time is probabilistic and depends on the number of sorties flown, the loss rate, and the rate at which air vehicles are replaced. The probability that exactly y air vehicles will be lost in S sorties is:

$$\frac{S!}{(S-y)!\,y!}\;(1-P_1)^{S-y}P_1^y$$

The rate at which air vehicles are replaced is determined by the resupply time (R) (the time from the loss of the third air vehicle to the return of the air vehicle cargo truck with replacements) and the number of air vehicle cargo trucks in the unit. The independent RPV section with a basic load of five air vehicles has only one air vehicle cargo truck. It will replace three air vehicles in R hours. The rear area launch and recovery section will have more than one air vehicle cargo truck. If it has N such trucks it can replace three air vehicles in $\frac{R}{N}$ hours.

If the length of the period considered is $\frac{R}{N}$ hours, the probability of having x air vehicles available at the start of a given period depends on the situation at the start of the previous period, losses during the period, and the addition of three air vehicles. Resupply is accomplished after three air vehicles have been lost. For the independent section with a basic load of five air vehicles, the probability of having five air vehicles at the start of a given resupply period is the probability of having five air vehicles available at the start of the previous period and losing none during the period plus the probability of having two air vehicles at the start of the previous period, being resupplied, and losing none.

The model for calculating the probability P(x) of having x air vehicles available, for a basic load of five air vehicles, is shown below where P[y] is the probability of having y air vehicles at the start of the previous resupply period and P(z) is the probability of losing z air vehicles during the previous period. The model can be extended for any basic load.

$$P(5) = P[5]\,P(0) + P[2]\,P(0)$$
$$P(4) = P[5]\,P(1) + P[4]\,P(0) + P[2]\,P(1) + P[1]\,P(0)$$
$$P(3) = P[5]\,P(2) + P[4]\,P(1) + P[3]\,P(0) + P[2]\,P(2) + P[1]\,P(1) + P[0]\,P(0)$$
$$P(2) = P[5]\,P(3) + P[4]\,P(2) + P[3]\,P(1) + P[2]\,P(3) + P[1]\,P(2) + P[0]\,P(1)$$
$$P(1) = P[5]\,P(4) + P[4]\,P(3) + P[3]\,P(2) + P[2]\,P(4) + P[1]\,P(3) + P[0]\,P(2)$$
$$P(0) = P[5]\,P(5) + P[4]\,(P(4) + P(5)) + P[3]\,(P(3) + P(4) + P(5)) + P[2]\,P(5) + P[1]\,(P(4) + P(5)) + P[0]\,(P(3) + P(4) + P(5))$$

F. PROBABILITY OF ACCOMPLISHING SORTIES

The probability that x air vehicles will be able to accomplish S sorties is derived differently for independent sections and rear area launch and recovery sections. For independent sections the probability that x air vehicles will accomplish S sorties is the probability that x-1 or less air vehicles will be lost in S sorties. This probability is derived by computing the probabilities that exactly y air vehicles will be lost in S sorties.

In the case of rear area launch and recovery in a division with four operations sections, five sorties are performed for the four sections. The probability that x air vehicles can accomplish S sorties is the probability that x/4 air vehicles can accomplish S/4 sorties with the result raised to the fourth power. When x is less, and S is greater, than the number of operations sections, the probability of accomplishing S sorties is zero since they must be attempted in the same time frame.

G. SORTIE POTENTIAL

The sortie potential for a given period is obtained by multiplying the probabilities that x air vehicles will be available by the probabilities that x air vehicles can accomplish S sorties and summing the products.

If the ratio of expected losses to replacements is greater than 1.0, sortie potential will continue to decline with time. When the ratio is less than 1.0, sortie potential will reach a state of equilibrium after some period of operation. The equilibrium state is used to calculate the estimates of sortie potential of divisions with independent sections and with rear area launch and recovery, shown in Figures B-1 through B-8.

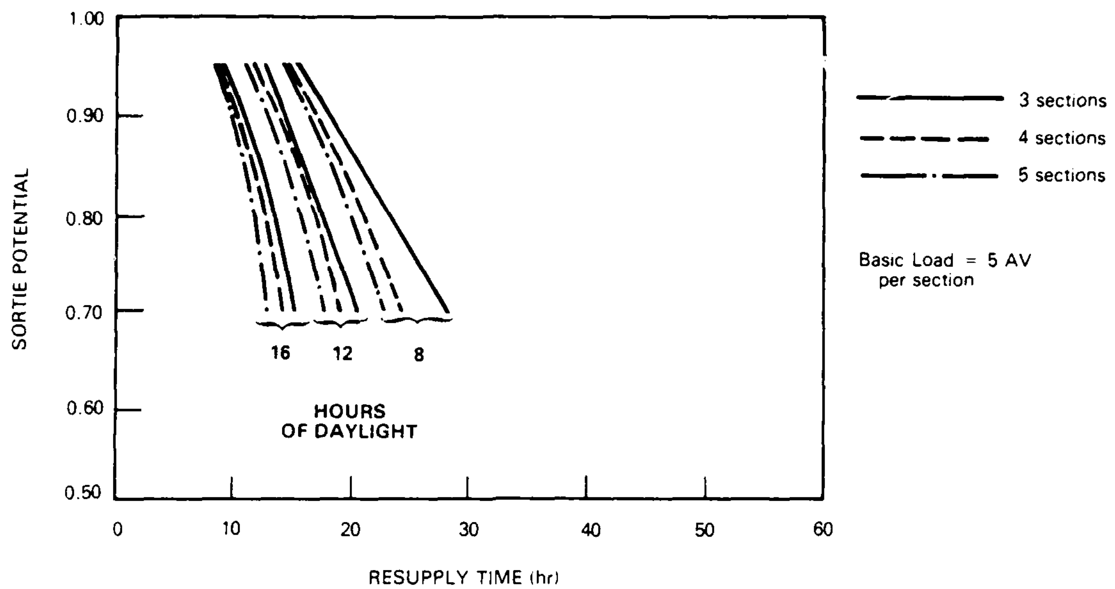

FIGURE B-1.
DAYLIGHT SORTIE POTENTIAL OF DIVISIONS
WITH INDEPENDENT SECTIONS
(P_I = 0.30)

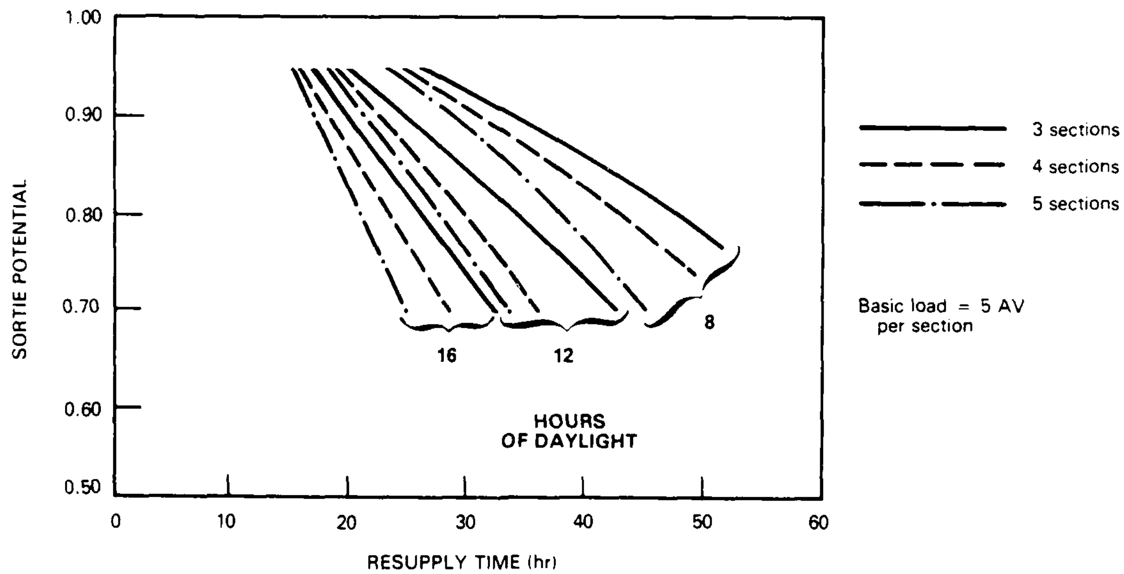

FIGURE B-2.
DAYLIGHT SORTIE POTENTIAL OF DIVISIONS
WITH INDEPENDENT SECTIONS
(P_I = 0.17)

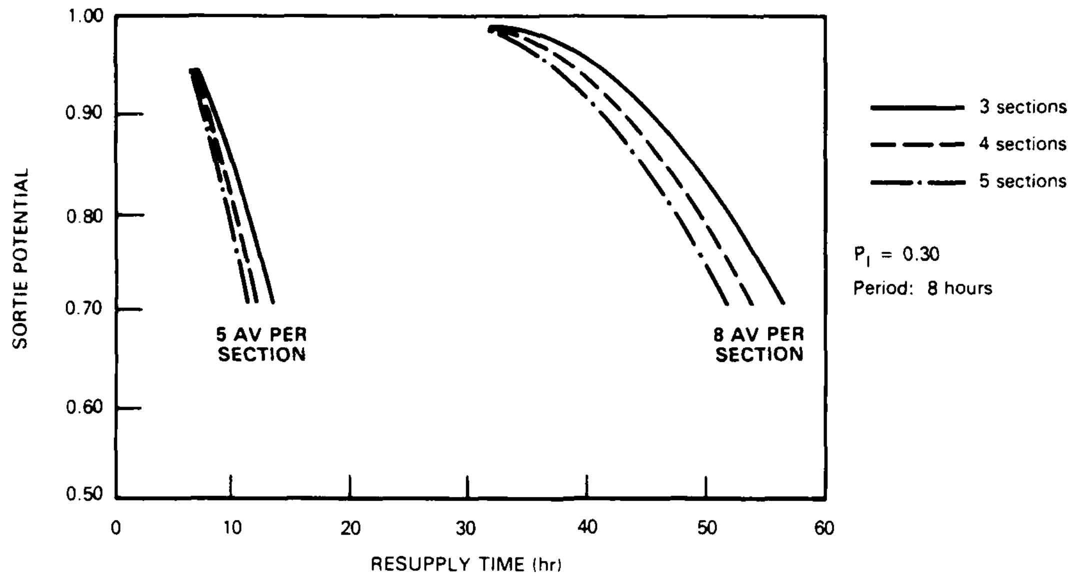

FIGURE B-3.
SORTIE POTENTIAL OF DIVISIONS WITH INDEPENDENT SECTIONS (Surge Situation)

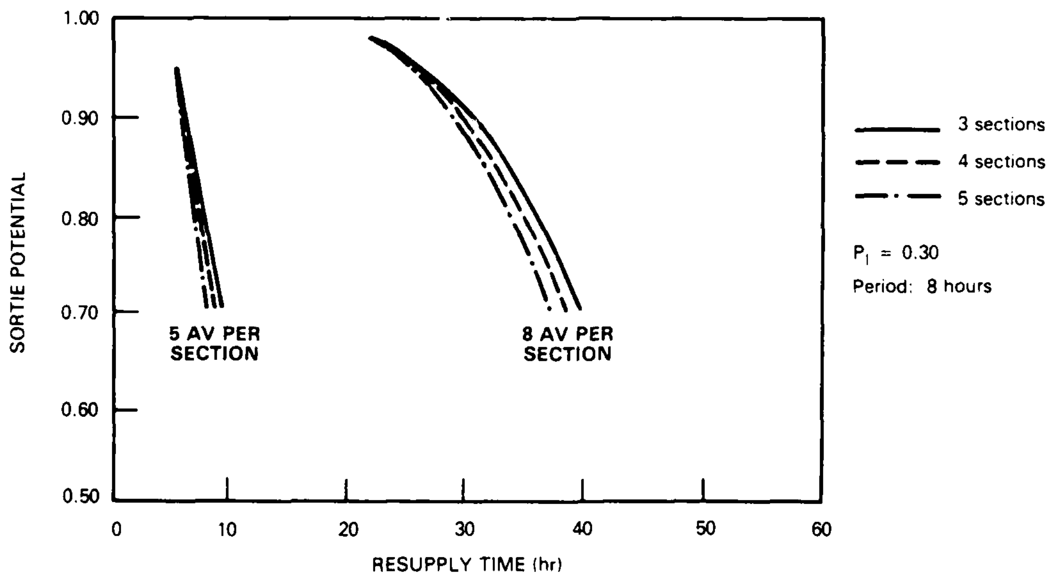

FIGURE B-4.
SORTIE POTENTIAL OF DIVISIONS WITH INDEPENDENT SECTIONS (All-Out Effort)

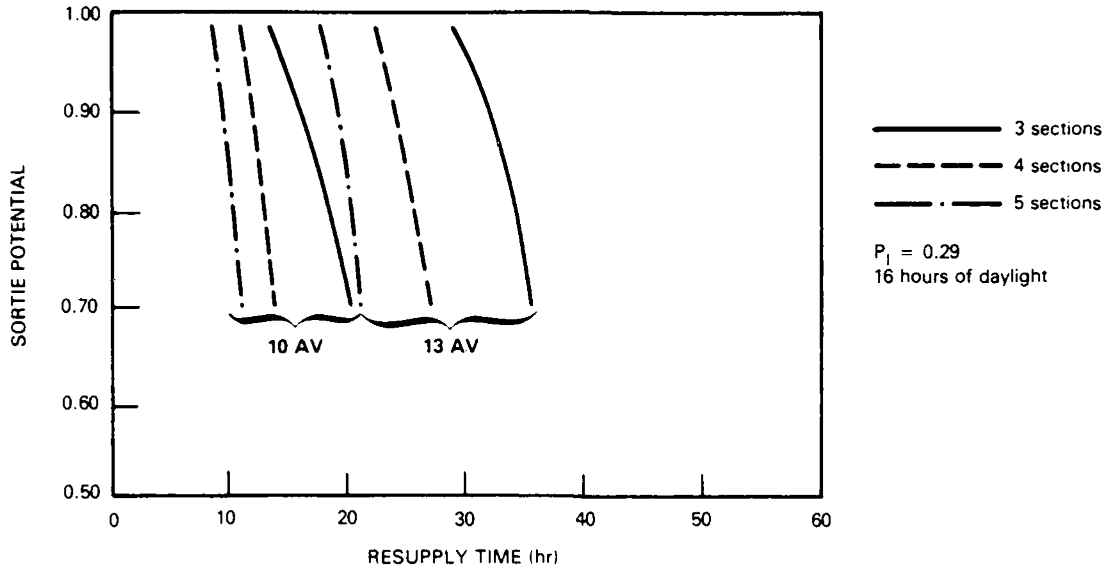

FIGURE B-5
DAYLIGHT SORTIE POTENTIAL OF DIVISIONS
WITH REAR AREA LAUNCH AND RECOVERY

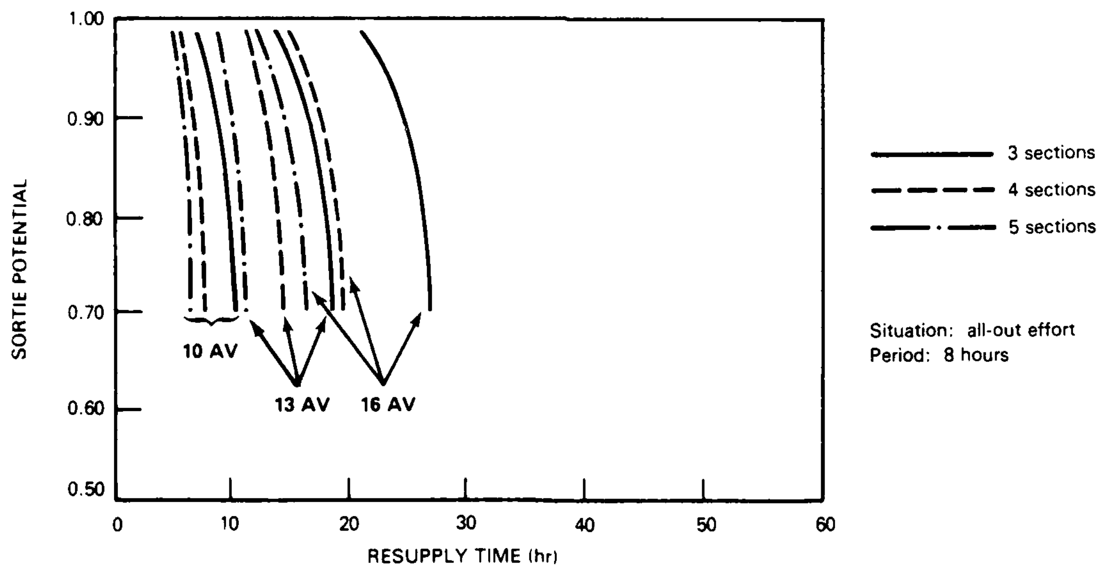

FIGURE B-6.
SORTIE POTENTIAL OF DIVISIONS
WITH REAR AREA LAUNCH AND RECOVERY
(P_I = 0.29)

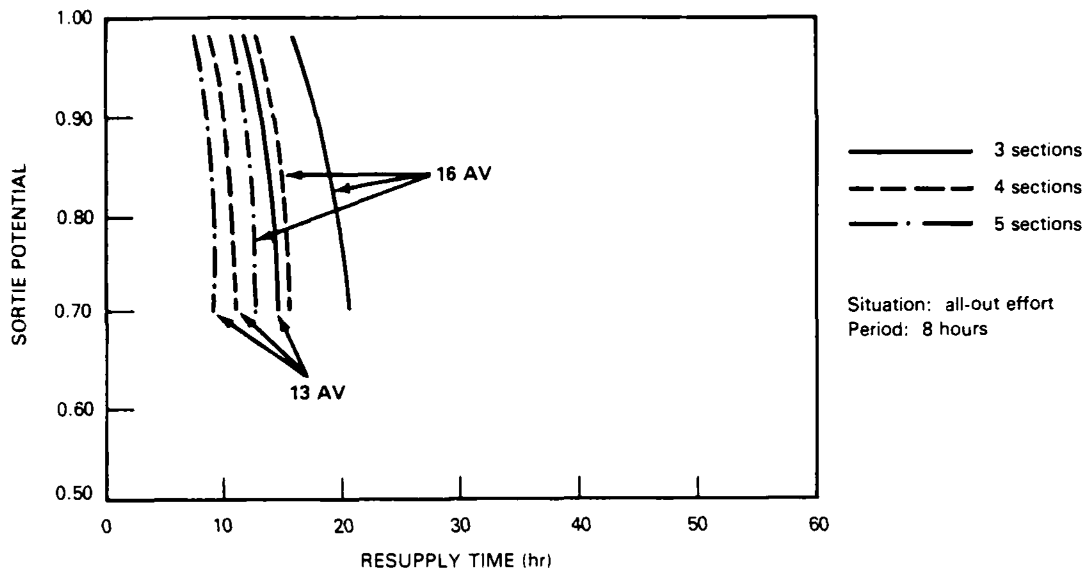

FIGURE B-7.
SORTIE POTENTIAL OF DIVISIONS
WITH REAR AREA LAUNCH AND RECOVERY
(P_I = 0.36)

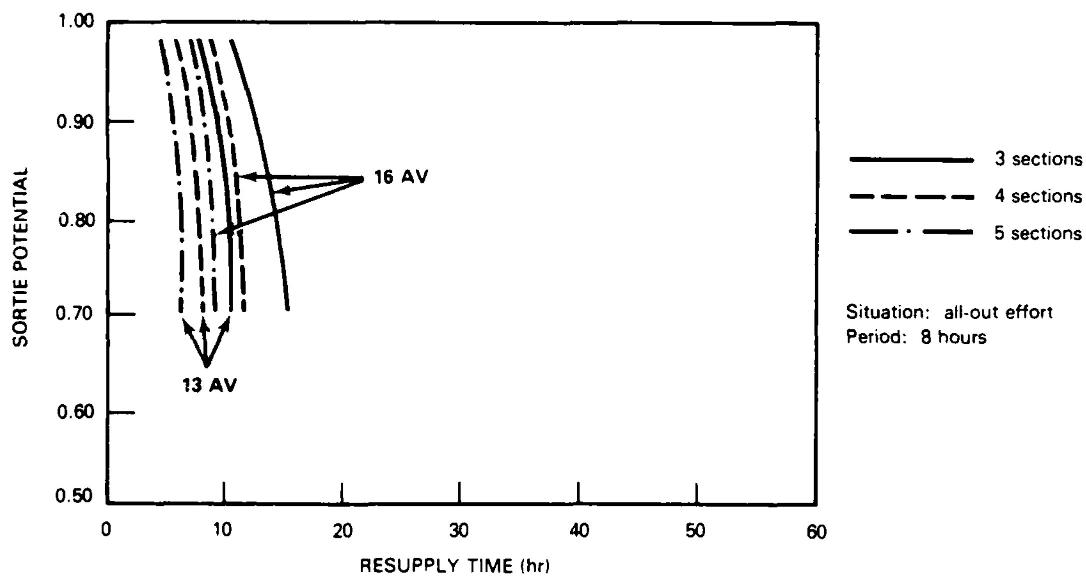

FIGURE B-8.
SORTIE POTENTIAL OF DIVISIONS
WITH REAR AREA LAUNCH AND RECOVERY
(P_I = 0.47)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study compared the operational potential of the RPV organization in a division that has rear area launch and recovery with that in a division that had independent sections. The study found that rear area launch and recovery could provide significant operational advantages including: a smaller basic load of air vehicles, more expeditious resupply of air vehicles, and reduced vulnerability of the ground systems. Reliable communications are required to make the rear area launch and recovery concept effective.

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